OF 2003-15

Open File

New Nouveau
Brunswick

Natural Resources
Minerals, Policy and Planning

# The Final Report on the St. Stephen Nickel Bioleach Project, Phase II

**DRD Services Inc.**

ISSN 1702-2649
ISBN 1-55236-989-7
Price: $8.00

2003

Open File 2003-15

# The Final Report on the St. Stephen Nickel Bioleach Project, Phase II

Recommended citation:

DRD Services Inc. 2003. The final report on the St. Stephen nickel bioleach project, Phase II. New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Open File 2003-15, 151 p.

---

Prepared for:

**Minerals, Policy and Planning Division**
Department of Natural Resources
Province of New Brunswick

**Hon. Keith Ashfield**
Minister of Natural Resources

October, 2003

New Nouveau
Brunswick

Natural Resources
Minerals, Policy and Planning

Open File 2003-15

# The Final Report on the St. Stephen Nickel Bioleach Project, Phase II

DRD Services Inc.

*This report has been prepared by DRD Services Inc., New Maryland, New Brunswick for Cobrun Mining Corp., Saint John, New Brunswick. The document has been published as received from the author.*
*Value-added/Mineral Processing Program report received January, 1 998.*

---

*Le présent rapport a été préparé par DRD Services Inc., de New Maryland, en Nouveau-Brunswick à l'intention de Cobrun Mining Corp., de Saint John, en Nouveau-Brunswick. Le document a été publié sous la forme où il a été reçu de l'auteur.*
*Rapport du Programme de traitement des minéraux à valeur ajoutée reçu en janvier 1998.*

ISSN 1702-2649
ISBN 1-55236-989-7
Price: $8.00

2003

# The
# Final Report
# on the
# St. Stephen Nickel Bioleach Project
# Phase II

*Prepared for*:

Cobrun Mining Corp.
63 Union St., P.O. Box 7079
Station A, St. John, N.B. E2L 4S5

*Prepared by*:

DRD Services Inc.
101 Shaw Lane
New Maryland, N.B. E3C 1H9

January, 1998

## Table of Contents

I. Acknowledgments and Disclosures . . . . . 3

II. Project Summary / Sommaire du projet . . . . . 4

III. Introduction . . . . . 7
    1.0 Project Objectives . . . . . 7
    2.0 Scope of Work . . . . . 7

IV. Project Methodology . . . . . 8
    1.0 Mineral Dressing Trials . . . . . 8
    2.0 Bench Scale Trials . . . . . 9
    3.0 Pilot Plant Trials . . . . . 12
    4.0 Metal Recovery and Flowsheet Development . . . . . 15
    5.0 Preliminary Engineering and Process Economics . . . . . 15

V. Results and Discussion . . . . . 16
    V.1 Mineral Dressing Trials . . . . . 16
    V.2 Bench Scale Trials . . . . . 20
    V.3 Pilot Plant Trials . . . . . 27
    V.4 Metal Recovery and Flowsheet Development . . . . . 36
    V.5 Preliminary Engineering and Process Economics . . . . . 40

VI. Conclusions and Recommendations . . . . . 46

VII. References . . . . . 47

## List of Figures and Tables

Figure 1. Stirred Flask Equipment Setup. . . . . 10
Figure 2. CSTR Pilot Plant Setup . . . . . 14
Figure 3. Metal Recovery vs Temperature - Incubator Trials . . . . . 21
Figure 4. NCSF Temperature Trials . . . . . 24
Figure 5. Solids Loading vs Metal Extraction. . . . . 26
Figure 6. Iron Loading vs Metal Extraction . . . . . 26
Figure 7. CSTR Metal Recovery - Tank N1a . . . . . 30
Figure 8. CSTR Metal Recovery - Tank N1b . . . . . 30
Figure 9. CSTR Metal Recovery - Tank N2 . . . . . 31
Figure 10. CSTR Metal Recovery - Tank N3 . . . . . 31
Figure 11. Bacterial Oxidation Flowsheet . . . . . 39
Figure 12. Metal Prices over 10 Years . . . . . 43

Table 1. TUNS Flotation Trials on St. Stephen Ore . . . . . 18
Table 2. Flotation Trials on Fresh core Samples . . . . . 19
Table 3. Summary of NCSF Test Results on Metal Recovery . . . . . 24
Table 4. Summary of CSTR Residue Assays . . . . . 29
Table 5. Temperature Trends in CSTR Trials . . . . . 33
Table 6. Acid Consumption Trends in CSTR Trials . . . . . 35
Table 7 CSTR Trials - Nitrogen Assays. . . . . 36
Table 8. Preliminary Financial Model Summary . . . . . 41
Table 9. Prices for Value Added Mineral Products . . . . . 44

## List of Appendices

Appendix A. Flotation Trials - Minerals Associates/Lakefield Research
Appendix B. TUNS Flotation Trials
Appendix C. CSTR Log Sheets
Appendix D. Flowsheet Development - Test Protocols
Appendix E. A Preliminary Financial Model
Appendix F. Incubator Shake Flask Trials - Test Results
Appendix G. Stirred Flask Trials - Test Results
Appendix H. CSTR Pilot Trials - Test Results

## Acknowledgements and Disclosures

Acknowledgements: Cobrun Mining Corp. (Cobrun) gratefully acknowledges the financial support of the Department of Natural Resources and Energy of the Province of New Brunswick through the Value Added Mineral Processing (*VAMP* - Project 9701) program and the National Research Council of Canada Industrial Research Assistance Program (*IRAP* - Project 04786E). These development programs have provided essential financial support to Cobrun through which it has been able to develop a bioleach technology that represents an economically viable solution for processing St. Stephen Nickel ore to value added mineral products.

Disclosures: Every effort has been made to ensure that the information in this document is accurate, but nothing herein contained, either expressed or implied, should be taken as a promise or representation to the future. This document is confidential and may not be reproduced, either in whole or in part, without the written authority of DRD Services Inc. and Cobrun Mining Corp.

All documents, reports, drawings, etc. prepared by DRD Services are 1998 copyright. All documents are prepared solely for the use of the client with whom DRD Services Inc. has entered an agreement.

Bacterial oxidation technology referred to in this document is the property of DRD Services Inc. and is licenced for use by Cobrun Mining Corp. Specific disclosure of any technical elements of the technology cannot be made to any parties without proper execution of a non-disclosure agreement.

## II. PROJECT SUMMARY

The St. Stephen Nickel Mine is a valuable New Brunswick resource that has excellent potential to employ 80-100 personnel for up to 5 years based on current conservative reserve estimates. For example, the ore in the recently defined open pit has a value in excess of $200/tonne.

The technical project that has been completed had the objective to define a process flowsheet to extract nickel and cobalt and to develop sufficient preliminary data on which basis a financial assessment could be made. The project succeeded by validating the bacterial oxidation process at the pilot scale with metal recoveries in the +90% range and by showing that a return on equity of +25% can be achieved for this property.

There are a number of technical achievements associated with this project that include:

- Flotation. In the area of mineral beneficiation, concentrates have been prepared having combined metal grades in the 8-10% range which could potentially be processed by a smelter. Attempts to achieve beneficiation on massive pyrrhotite have not been successful in the past. Combined metal grades of 3-5% at higher recoveries can also be produced and are excellent for bio-processing.
- Bio-Processing. Significant advances have been made in the bacterial oxidation process for base metal sulphides. In this program, novel bacterial populations have been developed that operate at thermophilic temperatures but which are atypical based on literature data. The test work has also shown that iron oxidation can be kept below 50% while the economic metals are extracted at +90%. In addition, the bacterial oxidation can be carried out without excessive acid consumption, at levels 50% of those expected for this system. Poor iron control/treatment and high acid consumption can often lead to excessive operating costs and render a project uneconomic..
- Process Flowsheet. Ferric ion solutions generated from the bacterial oxidation process can be used as a pre-leach of the concentrate feed at elevated temperatures and, at the same time, lower the ferric ion strength without resorting to expensive reducing agents. Some of the solution can be recycled in the process to optimize iron and copper loadings in solution as well as to reduce nutrient and acid demand.
- Value Added Mineral Products. It has been shown that bio-processing generates nickel, cobalt, and copper sulphates in solution with a minimum of other metal impurities. Purification of these solutions can potentially produce value added mineral products using solvent extraction (SX) techniques that have been developed for similar metal systems on a commercial basis.

A bankable feasibility study based on the operation of an integrated demonstration plant is required for commercial financing. Concurrently, process optimization can be carried out to further improve the process flowsheet. Processing to produce value added mineral products for test marketing purposes is highly recommended.

La mine de St. Stephen constitue une ressource néo-brunswickoise précieuse qui présente une excellente possibilité de fournir du travail à un personnel de 80 à 100 employés pendant une période pouvant atteindre cinq ans, d'après les données estimatives conservatrices courantes sur les réserves. Le minerai dans la zone à ciel ouvert récemment définie a par exemple une valeur de plus de 200 $/la tonne.

Le projet technique réalisé visait à définir un schéma simplifié de traitement en vue de l'extraction du nickel et du cobalt ainsi qu'à obtenir suffisamment de données préliminaires sur lesquelles pourrait être basée une évaluation financière. Le projet s'est avéré fructueux, car il a validé le procédé d'oxydation bactérienne à l'échelle préindustrielle avec des récupérations de métaux de l'ordre de plus de 90 % ainsi qu'en montrant qu'on peut obtenir un rendement des capitaux propres de plus de 25 % dans le cas de cette concession.

Ce projet a comporté l'examen d'un certain nombre de procédés techniques, notamment :

- La flottation. En ce qui a trait à l'enrichissement des minerais, on a préparé des concentrés ayant des teneurs combinées en métaux de l'ordre de 8 à 10 % qui poûrraient éventuellement être traités par une fonderie. Les tentatives d'obtention d'un enrichissement de la pyrrhotine massive ne s'étaient pas avérées fructueuses par le passé. On peut en outre produire des teneurs combinées en métaux de 3 à 5 % à des taux de récupération supérieurs et ces minerais conviennent très bien au traitement biotechnologique.

- La traitement biotechnologique. Des progrès marqués ont été réalisés dans le procédé d'oxydation bactérienne des sulfures de métaux communs. On a, dans le cadre de ce programme, mis au point des populations bactériennes nouvelles qui agissent à des températures thermophiles mais qui sont atypiques d'après les données de la documentation pertinente. Les travaux d'essais ont également révélé qu'on peut maintenir l'oxydation du fer au-dessous de 50 % tout en effectuant une extraction de plus de 90 % des métaux économiques. On peut de plus réaliser l'oxydation bactérienne sans consommation excessive d'acide, à des niveaux correspondant aux 50 % de ceux escomptés dans un tel système. Le traitement/contrôle médiocre du fer et la consommation élevée d'acide peuvent souvent aboutir à des coûts d'exploitation excessifs et rendre un projet peu économique.

- Le schéma simplifié de traitement. On peut utiliser les solutions d'ions ferriques obtenues de l'oxydation bactérienne comme agent de prélessivage du concentré d'alimentation à des températures élevées et abaisser en même temps le degré d'ions ferriques sans recourir à des agents réducteurs dispendieux. On peut recycler une certaine partie de la solution au cours du processus pour optimiser les charges de fer et de cuivre dans la solution ainsi que pour réduire les besoins en substances nutritives et en acide.

- Les produits minéraux à valeur ajoutée. Il a été démontré que le traitement biotechnologique produit du nickel, du cobalt et des sulfates de cuivre en solution avec un minimum d'autres impuretés métalliques. La purification de ces solutions pourrait permettre la production de produits minéraux à valeur ajoutée au moyen de techniques d'extraction par solvant (SX) mises au point aux fins de systèmes métalliques similaires à une échelle commerciale.

Il est essentiel d'effectuer une étude de faisabilité, au succès assuré, basée sur l'exploitation d'une usine-pilote intégrée pour obtenir un financement commercial. On peut, parallèlement, effectuer une optimisation du procédé employé pour améliorer davantage le schéma simplifié de traitement. Il est fortement recommandé d'effectuer un traitement fournissant des produits minéraux à valeur ajoutée aux fins des essais de commercialisation.

## III. INTRODUCTION

This document has been prepared for Cobrun Mining Corp. (Cobrun) and represents a technical assessment of the feasibility of starting a small mine operation at a rate of +500 tonnes per day (tpd) producing nickel, cobalt, and copper from their St. Stephen Nickel property located in Charlotte County, New Brunswick. This report is a follow up on previous work done by RPC, DRD Services, Kooiman, and others since 1987. The basis of work presented herein has been outlined in the project proposal, DRDP/97/01, entitled: "Pre-Feasibility Study on the Opening of the St. Stephen Nickel Mine"[1].

1.0 Project Objectives. The project had two primary objectives, *first,* to define a process flowsheet that both identifies and develops a method of nickel and cobalt extraction based on bacterial oxidation, *second*, to develop sufficient test data on which a preliminary engineering and cost estimate could be made for a commercial plant. A corollary objective was to develop an appropriate reagent scheme by which a nickel/cobalt/copper concentrate could be produced.

2.0 Scope of Work. The work undertaken to achieve those objectives cited above comprised the development and execution of a laboratory based technical program. The laboratory work included +60 bench scale bacterial oxidation tests, +60 days of continuous pilot testing, +10 flotation tests, and a pilot flotation trial. The execution of the test program was based on four laboratory structured tasks, and one engineering task. The scope of work was slightly altered from the original proposal[1] in that additional effort was placed on assessing fresh core material obtained from a recent drilling program. The assessment included a series of bacterial oxidation stirred flask tests and flotation tests. Assays of concentrates produced from fresh material will be used to assess their potential as a smelter feed. The re-alignment of the technical program resulted in a reduced level of effort on the metal recovery work.

## IV. Project Methodology

The project methodology to implement the work covered in the study was based on a series of structured technical tasks as follows:

Task 1. Mineral Dressing Trials. The development of a reagent recipe and flotation procedure was subcontracted to Minerals Associates and executed by Lakefield Research. The procedures, methods, etc. in the technical report is tabled in Appendix A. On receipt of the report the following pertinent technical procedures was summarized and sent to TUNS:

### *Flotation Trials*

| | |
|---|---|
| **Reagent Scheme**: | $Na_2CO_3$, SHQ(40% sodium silicate, 40% hexametaphosphate, and 20% Quebracho), PAX (potassium amyl xanthate), PM230 (Senmin). |
| **Grind Size**: | at least 80% -270 Mesh |
| **Procedure**: | The desired target is a combined metal grade of 8-10% at 80% metal recovery. A typical test comprises the addition of 3000 grams per tonne(gpt) of $Na_2CO_3$, 300 gpt SHQ, 20 gpt PAX/PM230(1:1) during grinding. Care needs to be taken during the addition to maximize the distribution of the reagents (e.g. for continuous grinding, drip in as opposed to mixing with the pulp). Typical conditioning (e.g. 1 minute) followed by froth collection in a flotation cell. In other tests 2 - 5 gpt of PAX/PM230 were added as collectors (e.g. 1st cleaner and scavenger) after grinding. |

TUNS carried out the balance of the flotation test work for both a 1 tonne pilot trial and on fresh core material obtained from a recent drilling program. TUNS technical reports on flotation trials and metal assays performed throughout the technical program are tabled in Appendix B.

Task 2. Bench Scale Trials. The bench scale bacterial oxidation batch trials that were conducted were of two types, A and B. Type A are stirred flask tests and type B are incubation shake flask tests. A typical standard operating procedure (SOP) has been developed for both cases and all test data generated and discussed in this report is based on the SOP protocol.

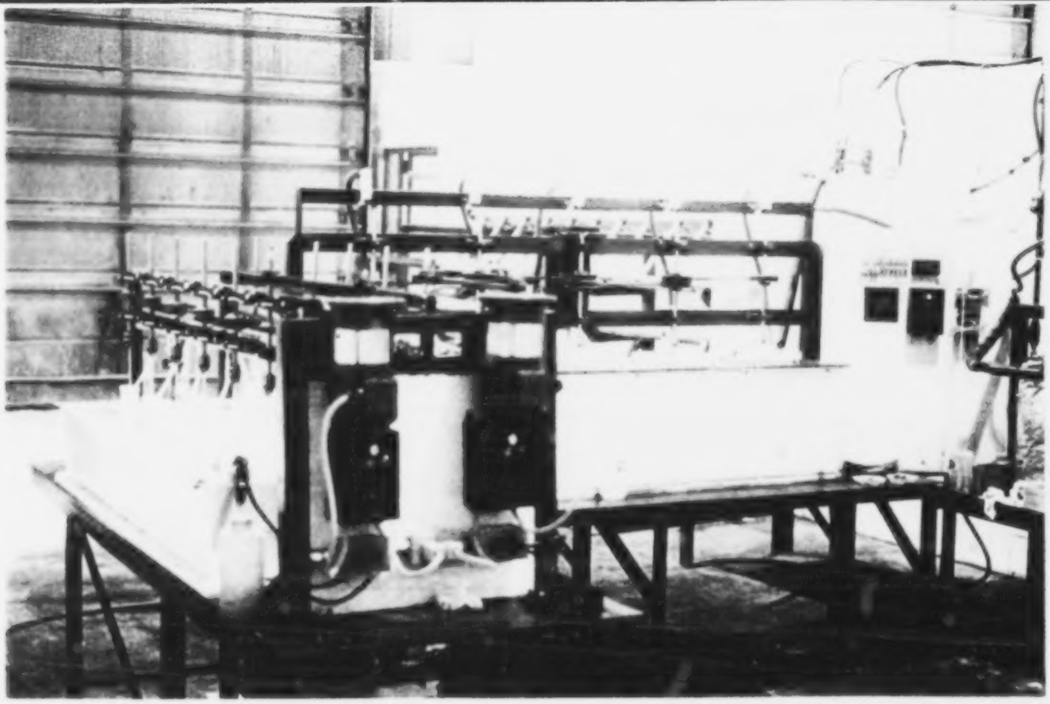
A. Stirred Flask Trials-NCSF's. Stirred flask bacterial oxidation tests are batch experiments conducted in duplicate that assess one process variable at a time. The standard set up for the NCSF's involves the placement of 6-2 litre Erlenmeyer flasks in a constant temperature bath (see the set up in Figure 1. In general, each test is run in duplicate so that in one series of 6 tests there are 3 duplicates and three ranges for the process variable under study.

Starting Reagents & Materials:

1. Acid Mine or Distilled Water (must be low in solution metal loadings)

2. Inoculum. This is a bacterial culture conditioned to the major process variables, in particular, temperature and pH. The development of an Inoculum comprises the basic features of a stirred flask test whereby pyrrhotite ore is placed in a vessel with a "9K" nutrient at 50°C at a pH of 1.2-1.5 with sulphuric acid addition. The bacteria multiply in this media and have a doubling rate of approximately 48 hours. After several weeks the culture population is strong enough (e.g. +200,000 counts/ml) to use as a seed inoculum for testwork. A properly conditioned tank can contain in excess of 1,000,000 counts/ml and counts of +30,000,000 have been observed in pilot trials.

3. Nutrients. Nutrient mixes are often labelled as "9K", the number referring to grams per litre (gpl) iron (e.g. "10K"being 10 gpl iron in solution). A typical nutrient mix for 10 litres would be 500g $FeSO_4.7H_2O$, 30g $(NH_4)_2SO_4$, 5g $MgSO_4.7H_2O$, 0.1g $Ca(NO_3)_2$, 5g $KH_2PO_4$, and 1g KCl.



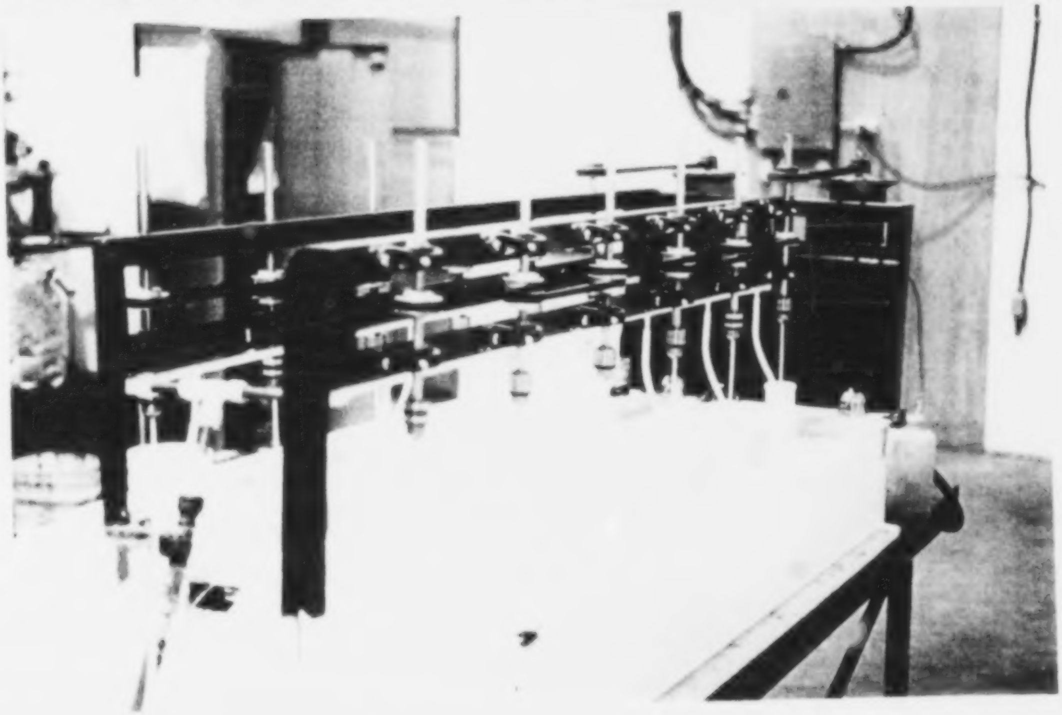


Figure 1 Photographs of Stirred Flask Assembly

4. Sulphide Ore/Concentrate. The ore/concentrate represents the feed material for the bacterial oxidation test and, generally, must be a sulphide material containing +10% sulphur.

Starting Procedure: A "9K" nutrient mixture is first added to acid mine water. The resultant nutrient broth is then inoculated with a bacterial culture developed specifically for the ore treated in a minimum 10:1 ratio of acid mine water to inoculum. In a typical test, 200 ml of inoculum is added to 1800 ml of acid mine water + nutrient for a total volume of 2 *l*. The batch test is maintained at a pre-set temperature (e.g. 40-55 °C), agitated, and aerated. The total mixture is adjusted to a pH = 0.6-1.8 by the addition of sulphuric acid. Once equilibrium conditions are established, 10% sulphides (e.g. for a 2 *l* test, 10% is equivalent to 200g of sulphide ore/concentrate) are added. Sometimes the feed material is added gradually over several days. A 10% solids loading is deemed to be the most suitable for the assessment of bio-oxidation potential for the specific ore/concentrate of interest. In commercial practice, higher solid loadings of 15% or 20% are used and these loadings are often evaluated.

Operating Conditions:

| | |
|---|---|
| Temperature: | 35-60 °C ( 45-60 °C for moderate thermophiles) |
| pH: | Maintained to <2.0 |
| Aeration: | Optimized to maintain > 2ppm oxygen in solution |
| Agitation: | Optimized to ensure complete homogeneity |
| Water Balance: | Water is added daily as make-up for evaporation |
| Sampling: | 5d/wk; Slurry withdrawn and solution checked for total iron and ferric and analysed for metals of interest |

Operating Strategy: The experiment is designed to both optimize and validate the bacterial oxidation potential of an ore/concentrate. Some key criteria that impact on performance include ferric ion/redox potential(ORP) and metal sulphate loadings in solution. Operating conditions are adjusted periodically to optimize metal extraction.

B. Incubator Shake Flask Trials-INC's. Incubator shake flask trials are distinguishable from the stirred flask trials in that they operate at a precision controlled temperature on a shaker platform. Similar protocols are used as described above with the exception that 1% solids are used for the tests since the method of agitation (e.g. shaking) does not give good dispersion of the solids at higher loadings. The flasks are also smaller, 250 ml, in size. In this program, the INC's were used primarily to assess the effect of temperature.

Task 3. Pilot Plant Trials. The test design and protocol used for the pilot plant trials are based on the **C**ontinuous **S**tirred **T**ank **R**eactor **(CSTR)** system that is used commercially for the treatment of refractory gold ores and/or concentrates. The pilot plant setup is based on a modified pilot plant system used by BacTech and Gencor for technical process studies. The modified CSTR system was designed specifically for the 10-30 liter( *l*) tank size and for the oxidation of base metal type concentrates. Some of the background information is in the public domain but is directed primarily to gold extraction and recovery. Very little data is available on sulphides especially on pyrrhotite based concentrates. The basic experimental design and approach for the CSTR trials is based on technical expertise provided by Signet Engineering and Vistatech who are recognized as leaders in the application of bacterial oxidation technology and who have provided technical expertise to DRD Services for previous technical programs. Signet Engineering have designed, commissioned and operated bacterial leach plants worldwide and are in a strong position to advise on the generation of data that will be adequate for commercial design and costing. Specific detail on setup and operations are as follows:

1.0 Experimental Setup. The pilot plant setup is based on 4 polyethylene tanks (15-20 *l*). An additional tank is used for feed solution make-up with appropriate additions of acid and nutrient (e.g. "9K"). All of the tanks are agitated with 4" diameter 4-blade Lightening A315 low shear agitators made of SAF2205 stainless steel. The agitator speed is adjusted (750 rpm) to maintain all solids in suspension. All tanks are aerated continuously to maintain Dissolved Oxygen (DO) at >2 ppm. At a head pressure of 110 psi and a setting of 2-3 SFCM on the flow meter, the tanks are >70% saturated in oxygen. Air is supplied through a compressor. The temperature in the tanks is controlled through a conventional hot water heater with a recirculating pump operating at atmospheric pressure. The tanks are all placed in the hot water bath and a temperature controller and relay maintain the preset temperature. Following this procedure, the temperature of the stirred tanks can be maintained within 0.5 degree of set point. Photographs of the CSTR pilot plant can be found in Figure 2.

2.0 Operations. Initially, all tanks are loaded with 10-15% solids (for example, 100g concentrate /1000 ml of acid mine water for a 10% solids loading). The solution contains nutrients adjusted for partial sulphur oxidation since not all of the iron is oxidized. Due to the high iron content in the sample studied, in most cases, no iron nutrient was added to the system. After equilibration of the system for a 5-10 days(d), continuous feeding is started. The desired pH is maintained by acid, $H_2SO_4$, addition. Operations are all based on a tank volume of 15 *l*. For semi-continuous operation, the first two tanks (la and 1b) were fed continuously in parallel at a rate based on a total preset retention time of 10d with Tanks 2 and 3 in series. The semi-continuous procedure was based on a 12 hour(h) addition rate (11 AM and 11 PM). For a 15% solids loading and a 10d retention time, the following procedure was carried out twice daily. 1.5 liters (*l*) of Tank 3 slurry was discharged to an overflow container, 1.5*l* of tank 2(t2) slurry was added to tank 3(t3), 750 ml of tank 1a (t1a) slurry and 750 ml of tank 1b(t1b) slurry was added to Tank 2, and 225g of concentrate in 750 ml feed solution was added to tank 1a and tank 1b. This feed procedure resulted in excellent experimental control and eliminated short circuiting and tank volume problems associated with other pilot systems. The CSTR is monitored on a daily basis and weekly log sheets document the pilot run. Once the system is operating well mechanically, operating conditions can be optimized. Key parameters that must be controlled during the run include maintaining solution

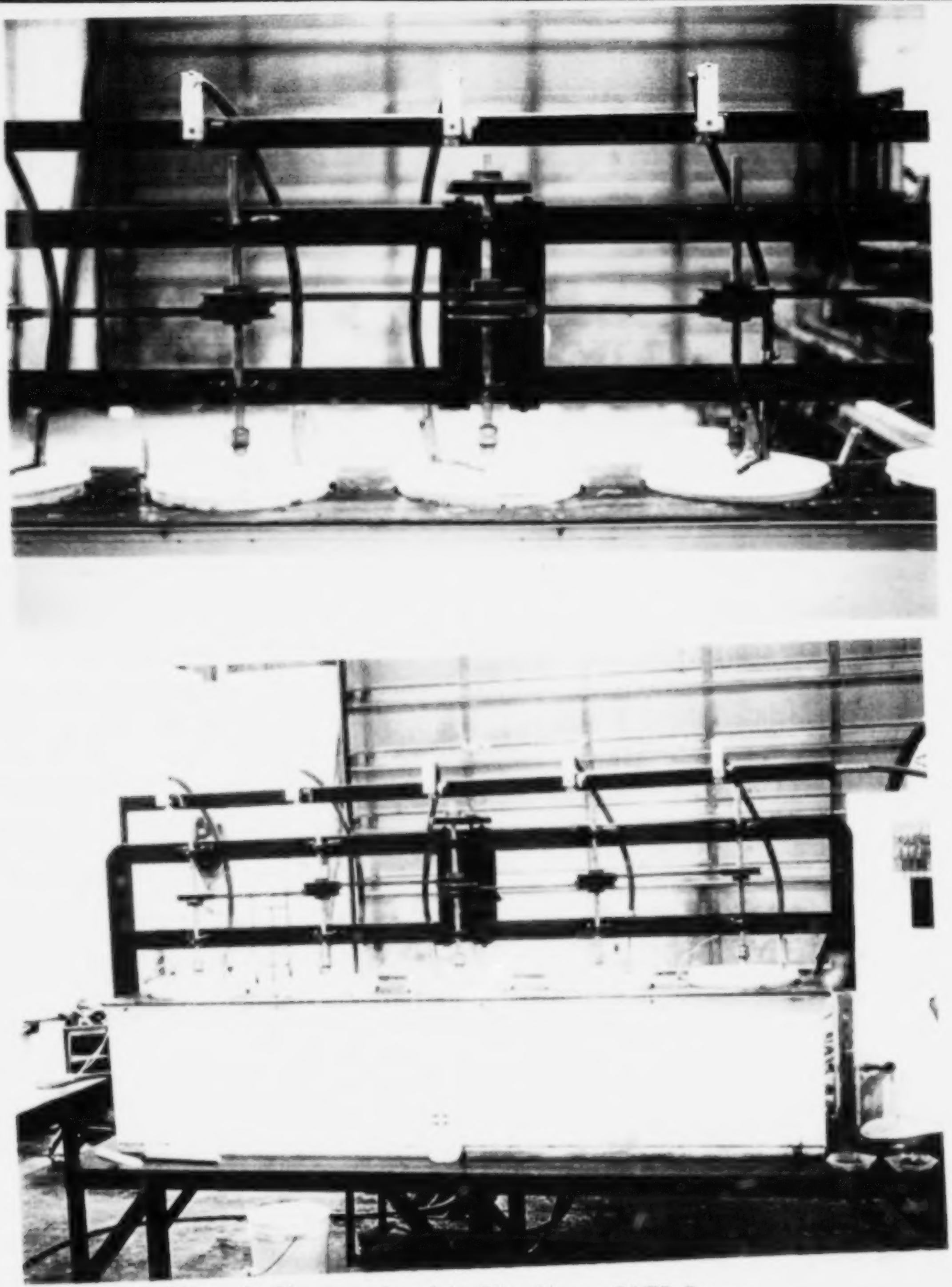


Figure 2. Photographs of the Pilot Plant - CSTR Setup

volume (15 *l*) in each tank, maintaining aeration conditions, and maintaining pH.

> 3.0 Technical Program. Based on a 10d retention time, tanks 1a and 1b are, theoretically, 100% exchanged by Day 5. Tank 2 is in equilibrium by Day 7.5 and Tank 3 is in equilibrium by Day 10. A tank 4 could be added to provide an additional 2.5d of retention time. In practice, equilibrium requires an additional 5-10d giving a total run time of 20 days for a given test condition. The sulphide oxidation rate can be monitored by iron loadings in solution by titration and copper, cobalt, and nickel (AA analysis) loadings in solution. The data collected during the CSTR trials was logged on a weekly basis (see CSTR log sheets; Appendix C).

Task 4. Metal Recovery and Flowsheet Development. The development of a conceptual flowsheet is based on literature data for nickel/cobalt recovery systems, on metal solution assays from the pilot overflow solution, and on a series of laboratory precipitation tests. The basic approach to the development of a bioleach type flowsheet is to devise the means to reduce all ferric ion to ferrous ion, to remove the copper, and to extract the nickel/cobalt with solvents (SX). An extensive test program integrated with a pilot trial at a demonstration level is required to validate a final flowsheet. Specific test protocols (see Appendix D) have been developed for the simple solution tests conducted in this program.

Task 5. Preliminary Engineering and Process Economics. Based on the test data, a model has been developed for the bacterial oxidation step (see Appendix E) to establish preliminary engineering costs. The process economics have been developed for a base case and the results are tabled in Appendix E.

## V. Results and Discussion

The experimental data generated in this technical program has been presented and discussed, in large part, in the monthly progress reports. These reports are tabled in the Volume II of this report and copies have been given to the VAMP chair and to the NRC IRAP coordinator. The following discussion will summarize the key points and issues arising from this work.

V.1 Mineral Dressing Trials. Flotation trials were conducted in three phases.

In the *first* phase, flotation studies were undertaken at Lakefield Research under the direction and management by Minerals Associates (see Appendix A). The objectives of the test program was to determine if the ore was amenable to flotation beneficiation and to provide sufficient procedural information for the operation of a small pilot plant that would generate a bulk concentrate. It should be noted that previous flotation work conducted on similar samples indicated very poor metal recoveries except for copper. This study established that all samples tested were amenable to beneficiation and established a reagent scheme/procedure. A number of issues arising from this preliminary investigation included:

1. Sampling. Most of the samples evaluated were partially oxidized and this effect will definitely impact negatively on the beneficiation results. The samples were not representative of the bulk sulphide zone and further work on a better sample was recommended. Further work in this regard is described in the following section.

2. Liberation/Grind size. Initial work examined grind size as the main process variable. At finer grind sizes, performance decreased indicating that some alternative processing that would include high intensity conditioning might be suitable.

3. Grade vs Recovery. In some cases, copper recoveries of 96% and nickel/cobalt

recoveries of +87% were achieved. However, while these recoveries are excellent, the concentrate grades were very low. For example, at these high recoveries, the mass reduction from ore to concentrate was only 50% resulting in a doubling of the original ore grade. This effect was obtained in a previous study conducted by R. May in an RPC report[2]. Tighter control on grind size and locked cycle testing on fresh, non-oxidized samples may improve current results.

In conclusion, higher mass reductions from ore to concentrate of approximately 4:1 with +80% metal recovery will be required to justify the capital and operating costs of a beneficiation process. This work did show some advance over previous work and future test work should provide improved results.

In the ***second*** phase, a bulk ore sample was processed at TUNS using those conditions established at Lakefield. Prior to operating the pilot plant, a series of laboratory tests were carried out to familiarize TUNS on the reagent scheme and operating conditions as well as to assess the response of the bulk sample. The results of the lab tests are summarized in Table 1 and the technical report on the pilot run is tabled in Appendix B. Table 1 shows that good recoveries were achieved for copper but were low for cobalt and nickel. Test FT2 gave the best result and recoveries were 66% nickel, 80% cobalt, and 91% copper at a ore to concentrate ratio of 4:1 and a combined metal grade of 5.7%. It is worth noting that the cobalt recoveries in all tests were consistently higher suggesting that the cobalt mineralogy is slightly different. In the pilot trials the final concentrate graded 2.6% Ni, 0.24% Co, and 4.3%. This concentrate was used for the CSTR trials.

In the ***third*** phase, TUNS repeated bench scale studies on a fresh core sample obtained from the drilling program conducted in the Fall, 1997. The test results are tabled in Appendix B and summarized in Table 2. A number of general observations can be made about these tests. The use of a fresh sample obtained from core demonstrated much improved metal recoveries at higher ore:concentrate ratios. As well, concentrates having a combined metal grade in the range of 8-10%

Table 1a TUNS Flotation Trials on St. Stephen Ore

| FT1 | | | Metal Recovery | | | Metal Grades | |
|---|---|---|---|---|---|---|---|
| Flotation Test - Core | Wt. % | Ni | Co | Cu | Ni | Co | Cu |
| Cleaner Concentrate | 7.84% | 11.80% | 13.50% | 53.28% | 2.17% | 0.156% | 4.29% |
| 3rd Cleaner Tail | | 0.00% | 0.00% | 0.00% | | | |
| 2nd Cleaner Tail | | 0.00% | 0.00% | 0.00% | | | |
| 1st Cleaner Tail | | 0.00% | 0.00% | 0.00% | | | |
| *(1)Rougher Concentrate(Calc.)* | ***7.84%*** | ***11.80%*** | ***13.50%*** | ***53.28%*** | ***2.17%*** | ***0.156%*** | ***4.29%*** |
| *(2) Cleaner Concentrate +2nd/3rd(Calc.)* | ***7.84%*** | ***11.80%*** | ***13.50%*** | ***53.28%*** | ***2.17%*** | ***0.156%*** | ***4.29%*** |
| Rougher Tail | 92.16% | 88.20% | 86.50% | 46.72% | 1.38% | 0.085% | 0.32% |
| Calculated Head | 100.00% | 100.00% | 100.00% | 100.00% | 1.442% | 0.091% | 0.631% |
| Mass Recovery Factor(1) | **12.8** | | | | Combined Metal Grade(1) = | | ***6.6%*** |
| Mass Recovery Factor(2) | **12.8** | | | | Combined Metal Grade(2) = | | ***6.6%*** |

Table 1b TUNS Flotation Trials on St. Stephen Ore

| FT2 | | | Metal Recovery | | | Metal Grades | |
|---|---|---|---|---|---|---|---|
| Flotation Test - Core | Wt. % | Ni | Co | Cu | Ni | Co | Cu |
| Cleaner Concentrate | 8.94% | 35.28% | 45.77% | 86.14% | 5.59% | 0.472% | 6.00% |
| 3rd Cleaner Tail | | 0.00% | 0.00% | 0.00% | | | |
| 2nd Cleaner Tail | | 0.00% | 0.00% | 0.00% | | | |
| 1st Cleaner Tail | 18.94% | 30.62% | 33.90% | 5.17% | 2.29% | 0.165% | 0.17% |
| *(1)Rougher Concentrate(Calc.)* | ***27.88%*** | ***65.89%*** | ***79.66%*** | ***91.31%*** | ***3.35%*** | ***0.263%*** | ***2.04%*** |
| *(2) Cleaner Concentrate +2nd/3rd(Calc.)* | ***8.94%*** | ***35.28%*** | ***45.77%*** | ***86.14%*** | ***5.59%*** | ***0.472%*** | ***6.00%*** |
| Rougher Tail | 72.12% | 34.11% | 20.34% | 8.69% | 0.67% | 0.026% | 0.08% |
| Calculated Head | 100.00% | 100.00% | 100.00% | 100.00% | 1.417% | 0.092% | 0.623% |
| Mass Recovery Factor(1) | **3.6** | | | | Combined Metal Grade(1) = | | ***5.7%*** |
| Mass Recovery Factor(2) | **11.2** | | | | Combined Metal Grade(2) = | | ***12.1%*** |

Table 1c TUNS Flotation Trials on St. Stephen Ore

| FT3 | | | Metal Recovery | | | Metal Grades | |
|---|---|---|---|---|---|---|---|
| Flotation Test - Core | Wt. % | Ni | Co | Cu | Ni | Co | Cu |
| Cleaner Concentrate | 15.66% | 43.24% | 52.56% | 85.42% | 3.90% | 0.315% | 3.35% |
| 3rd Cleaner Tail | | 0.00% | 0.00% | 0.00% | | | |
| 2nd Cleaner Tail | 20.96% | 28.94% | 28.81% | 5.80% | 1.95% | 0.129% | 0.17% |
| 1st Cleaner Tail | 17.41% | 11.22% | 8.35% | 2.64% | 0.91% | 0.045% | 0.09% |
| *(1)Rougher Concentrate(Calc.)* | ***54.03%*** | ***83.40%*** | ***89.71%*** | ***93.86%*** | ***2.18%*** | ***0.156%*** | ***1.07%*** |
| *(2) Cleaner Concentrate +2nd/3rd(Calc.)* | ***36.62%*** | ***72.18%*** | ***81.37%*** | ***91.22%*** | ***2.78%*** | ***0.209%*** | ***1.53%*** |
| Rougher Tail | 45.97% | 16.60% | 10.29% | 6.14% | 0.51% | 0.021% | 0.08% |
| Calculated Head | 100.00% | 100.00% | 100.00% | 100.00% | 1.412% | 0.094% | 0.614% |
| Mass Recovery Factor(1) | **1.9** | | | | Combined Metal Grade(1) = | | ***3.4%*** |
| Mass Recovery Factor(2) | **2.7** | | | | Combined Metal Grade(2) = | | ***4.5%*** |

Table 1d TUNS Flotation Trials on St. Stephen Ore

| FT4 | | | Metal Recovery | | | Metal Grades | |
|---|---|---|---|---|---|---|---|
| Flotation Test - Core | Wt. % | Ni | Co | Cu | Ni | Co | Cu |
| Cleaner Concentrate | 3.70% | 12.30% | 15.44% | 69.22% | 4.88% | 0.392% | 11.24% |
| 3rd Cleaner Tail | | 0.00% | 0.00% | 0.00% | | | |
| 2nd Cleaner Tail | 5.55% | 13.69% | 17.01% | 8.41% | 3.62% | 0.268% | 0.91% |
| 1st Cleaner Tail | 36.12% | 50.20% | 57.67% | 16.83% | 2.04% | 0.150% | 0.28% |
| *(1)Rougher Concentrate(Calc.)* | ***45.37%*** | ***76.18%*** | ***90.12%*** | ***94.45%*** | ***2.46%*** | ***0.187%*** | ***1.25%*** |
| *(2) Cleaner Concentrate +2nd/3rd(Calc.)* | ***9.25%*** | ***25.99%*** | ***32.45%*** | ***77.62%*** | ***4.12%*** | ***0.330%*** | ***5.04%*** |
| Rougher Tail | 54.63% | 23.82% | 9.88% | 5.55% | 0.64% | 0.017% | 0.06% |
| Calculated Head | 100.00% | 100.00% | 100.00% | 100.00% | 1.468% | 0.094% | 0.601% |
| Mass Recovery Factor(1) | **2.2** | | | | Combined Metal Grade(1) = | | ***3.9%*** |
| Mass Recovery Factor(2) | **10.8** | | | | Combined Metal Grade(2) = | | ***9.5%*** |

Table 1e TUNS Flotation Trials on St. Stephen Ore

| FT5 | | | Metal Recovery | | | Metal Grades | |
|---|---|---|---|---|---|---|---|
| Flotation Test - Core | Wt. % | Ni | Co | Cu | Ni | Co | Cu |
| Cleaner Concentrate | 5.74% | 15.90% | 19.13% | 77.78% | 4.22% | 0.350% | 8.24% |
| 3rd Cleaner Tail | 10.65% | 27.96% | 30.32% | 9.81% | 4.00% | 0.299% | 0.56% |
| 2nd Cleaner Tail | 17.12% | 25.39% | 25.43% | 4.22% | 2.26% | 0.156% | 0.15% |
| 1st Cleaner Tail | 11.95% | 7.14% | 9.56% | 2.36% | 0.91% | 0.084% | 0.12% |
| *(1)Rougher Concentrate(Calc.)* | ***45.46%*** | ***76.38%*** | ***84.42%*** | ***94.17%*** | ***2.56%*** | ***0.195%*** | ***1.26%*** |
| *(2) Cleaner Concentrate +2nd/3rd(Calc.)* | ***33.51%*** | ***69.24%*** | ***74.87%*** | ***91.81%*** | ***3.15%*** | ***0.235%*** | ***1.67%*** |
| Rougher Tail | 54.54% | 23.62% | 15.58% | 5.83% | 0.66% | 0.030% | 0.07% |
| Calculated Head | 100.00% | 100.00% | 100.00% | 100.00% | 1.524% | 0.105% | 0.608% |
| Mass Recovery Factor(1) | **2.2** | | | | Combined Metal Grade(1) = | | ***4.0%*** |
| Mass Recovery Factor(2) | **3.0** | | | | Combined Metal Grade(2) = | | ***5.0%*** |

### Table 2a Flotation Trials on Fresh Core Samples

| FTC - 1<br>Flotation Test - Core | | Metal Recovery | | | Metal Grades | | |
|---|---|---|---|---|---|---|---|
| | Wt. % | Ni | Co | Cu | Ni | Co | Cu |
| Cleaner Concentrate | 8.53% | 54.41% | 68.57% | 81.39% | 9.17% | 0.735% | 6.12% |
| 3rd Cleaner Tail | 4.78% | 8.78% | 9.28% | 4.70% | 2.64% | 0.192% | 0.63% |
| 2nd Cleaner Tail | 6.91% | 6.10% | 5.73% | 2.37% | 1.27% | 0.082% | 0.22% |
| 1st Cleaner Tail | 15.67% | 7.96% | 4.75% | 2.35% | 0.73% | 0.030% | 0.10% |
| ***(1)Rougher Concentrate(Calc.)*** | ***35.89%*** | ***77.25%*** | ***88.33%*** | ***90.80%*** | ***3.09%*** | ***0.243%*** | ***1.62%*** |
| ***(2) Cleaner Concentrate +2nd/3rd(Calc.)*** | ***20.22%*** | ***69.30%*** | ***83.58%*** | ***88.46%*** | ***4.93%*** | ***0.409%*** | ***2.81%*** |
| Rougher Tail | 64.11% | 22.75% | 11.67% | 9.20% | 0.51% | 0.018% | 0.09% |
| Calculated Head | 100.00% | 100.00% | 100.00% | 100.00% | 1.438% | 0.099% | 0.641% |
| Mass Recovery Factor(1) | **2.8** | | | | **Combined Metal Grade(1) =** | | ***5.0%*** |
| Mass Recovery Factor(2) | **4.9** | | | | **Combined Metal Grade(2) =** | | ***8.1%*** |

### Table 2b. Flotation Trials on Fresh Core Samples

| FTC - 2<br>Flotation Test - Core | | Metal Recovery | | | Metal Grades | | |
|---|---|---|---|---|---|---|---|
| | Wt. % | Ni | Co | Cu | Ni | Co | Cu |
| Cleaner Concentrate | 3.83% | 33.34% | 41.96% | 59.61% | 13.40% | 1.230% | 10.63% |
| 3rd Cleaner Tail | 3.32% | 14.02% | 16.92% | 13.61% | 6.50% | 0.572% | 2.80% |
| 2nd Cleaner Tail | 8.60% | 16.93% | 20.38% | 13.47% | 3.03% | 0.266% | 1.07% |
| 1st Cleaner Tail | 18.27% | 12.58% | 7.81% | 4.41% | 1.06% | 0.048% | 0.17% |
| ***(1)Rougher Concentrate(Calc.)*** | ***34.02%*** | ***76.86%*** | ***87.07%*** | ***91.11%*** | ***3.48%*** | ***0.287%*** | ***1.83%*** |
| ***(2) Cleaner Concentrate +2nd/3rd(Calc.)*** | ***15.75%*** | ***64.28%*** | ***79.26%*** | ***86.70%*** | ***6.28%*** | ***0.565%*** | ***3.76%*** |
| Rougher Tail | 65.98% | 23.14% | 12.93% | 8.89% | 0.54% | 0.022% | 0.09% |
| Calculated Head | 100.00% | 100.00% | 100.00% | 100.00% | 1.540% | 0.112% | 0.683% |
| Mass Recovery Factor(1) | **2.9** | | | | **Combined Metal Grade(1) =** | | ***5.6%*** |
| Mass Recovery Factor(2) | **6.3** | | | | **Combined Metal Grade(2) =** | | ***10.6%*** |

### Table 2c. Flotation Trials on Fresh Core Samples

| FTC - 3<br>Flotation Test - Core | | Metal Recovery | | | Metal Grades | | |
|---|---|---|---|---|---|---|---|
| | Wt. % | Ni | Co | Cu | Ni | Co | Cu |
| Cleaner Concentrate | 12.63% | 61.21% | 77.50% | 85.24% | 7.40% | 0.677% | 4.80% |
| 3rd Cleaner Tail | 5.80% | 6.08% | 4.42% | 2.84% | 1.60% | 0.084% | 0.35% |
| 2nd Cleaner Tail | 12.89% | 8.36% | 5.96% | 3.23% | 0.99% | 0.051% | 0.18% |
| 1st Cleaner Tail | 16.82% | 7.38% | 3.66% | 2.13% | 0.67% | 0.024% | 0.09% |
| ***(1)Rougher Concentrate(Calc.)*** | ***48.14%*** | ***83.02%*** | ***91.54%*** | ***93.44%*** | ***2.63%*** | ***0.210%*** | ***1.38%*** |
| ***(2) Cleaner Concentrate +2nd/3rd(Calc.)*** | ***31.32%*** | ***75.64%*** | ***87.88%*** | ***91.31%*** | ***3.69%*** | ***0.310%*** | ***2.07%*** |
| Rougher Tail | 51.86% | 16.98% | 8.46% | 6.56% | 0.500% | 0.018% | 0.090% |
| Calculated Head | 100.00% | 100.00% | 100.00% | 100.00% | 1.527% | 0.110% | 0.711% |
| Mass Recovery Factor(1) | **2.1** | | | | **Combined Metal Grade(1) =** | | ***4.2%*** |
| Mass Recovery Factor(2) | **3.2** | | | | **Combined Metal Grade(2) =** | | ***6.1%*** |

were obtained. Obviously, lower mass recoveries to concentrate gave lower metal recoveries. At a 3:1 upgrade ratio, recoveries for nickel, cobalt, and copper were 78%, 89%, and 91%, respectively. In these trials, the ore was ground to 80% passing 45 microns. It is worth noting that nickel recoveries were generally lower than cobalt. Further work is required on this material to examine the effect of grind size and to assess the mineralogy. Under current operating conditions, too much metal value is reporting to the tails. Improved recoveries may be made through locked cycle testing, through optimal grinding (either primary or secondary), or through the use of high intensity conditioning. These results also indicate that there may be some economic merit in producing two product lines, a higher value concentrate for a smelter and a lower grade concentrate for value added processing.

**V.2 Bench Scale Trials**. The bench scale trials were comprised of two parts which were operated concurrently, namely, the incubator, INC, trials and the stirred flask, NCSF, trials.

V.2.1 Incubator Shake Flask Trials(INC's). Five series of shake flask trials which were primarily designed to assess the effect of pH and temperature (44°C, 50°C, 52°C, 54°C, and 58°C) on metal extraction. The tests were conducted in duplicate and at 3 pH's, namely: 1.2, 1.5, and 1.8. The iron titration results (Table F1) of the final solutions from these experiments, graphs of pH versus metal extraction (Figures F1 and F2), and residue assay calculations (Table F2 to F6) are tabled in Appendix F. The following general conclusions were made from the results of these experiments:

1. pH. In general, increasing pH gave a small decrease in metal extraction. For example, In the case of iron, the decline in recovery was +20%. At higher pH, some of the iron may be precipitating as a goethite. The differences in metal extractions over the pH range tested was of the order of 2%. For example, in INC-58, Table F6 and Figure F2, the cobalt recovery was 94.5%, 96.0%, and 93.8% over the pH range 1.3, 1.5, and 1.8, respectively.

2. Metal Recovery. A combination of a low solids loading and a relatively long retention

time will yield high metal recoveries in these trials. However, there are clear differences in extraction as a function of temperature. This result is illustrated in Figure 3 where, for example, the recovery of cobalt increased from 89% at 50°C to 96% at 58°C. Extractions in the +90% range were achieved in most trials with the exception of iron which was usually in the -50% range. In the INC-54 trial, and additional assessment was made on the impact of retention time. As illustrated in Figure F3 and Table F4, the retention time steadily increased from day 5 to day 15. It is interesting to note that the cobalt and nickel extraction was in the order of +90% by day 15. Considering that the inoculum is not optimized or conditioned to the settings, it would seem reasonable to conclude that recoveries of +90% should be achievable in less than 15 days.

V.2.2 Bench Scale Stirred Flask Trials (NCSF's). Ten(10) test series of NCSF's were completed for a total of 60 individual tests, each test taking 18-20 days for completion. These series of bench scale trials studied the effect of pH and temperature (Series 2,3,4,5,8,9), solids loading (Series 6), iron loading (Series 7), and feed material (Series 10). The test results are tabled in Appendix G. The test protocol for each series is tabled either in Table G1 or in Table G2. In order to conduct these tests, it was necessary to prepare an inoculum conditioned to the ore under treatment. The culture was developed in a 30 liter tank and was started in April, 1997. The tank was monitored for iron oxidation and the results are tabled in Table G3a and G3b. The culture, labeled NCT30, was used as the seed inoculum for all the NCSF trials with exception to Series 1 and 10. Series 1 was used to establish operating procedures.

V.2.2.1 Iron Effects. The iron assays on solutions from the NCSF trials that was obtained from titration data can be found in Table G4 for Series 1-5 and in Table G5 for Series 6-10. The iron assays give an indication on how well the bacterial oxidation process is working. The ferric ion strength in solution also gives a strong indication on the status of the experiment. For example, at the end of the experiment the ferric ion level increases and is closely related to the level of oxidation. The production of ferric ion from ferrous ion is

**Metal Recovery as a Function of Temperature**
**Temperature (deg C); pH = 1.5**

| 48 | 50 | 52 | 54 | 58 | |
|---|---|---|---|---|---|
| 33.7% | 37.7% | 0.0% | 10.42% | 46.73% | Fe |
| 72.4% | 85.8% | 55.9% | 92.14% | 95.23% | Cu |
| 97.2% | 90.7% | 91.8% | 95.06% | 97.72% | Ni |
| 96.0% | 88.9% | 89.4% | 93.66% | 96.04% | Co |

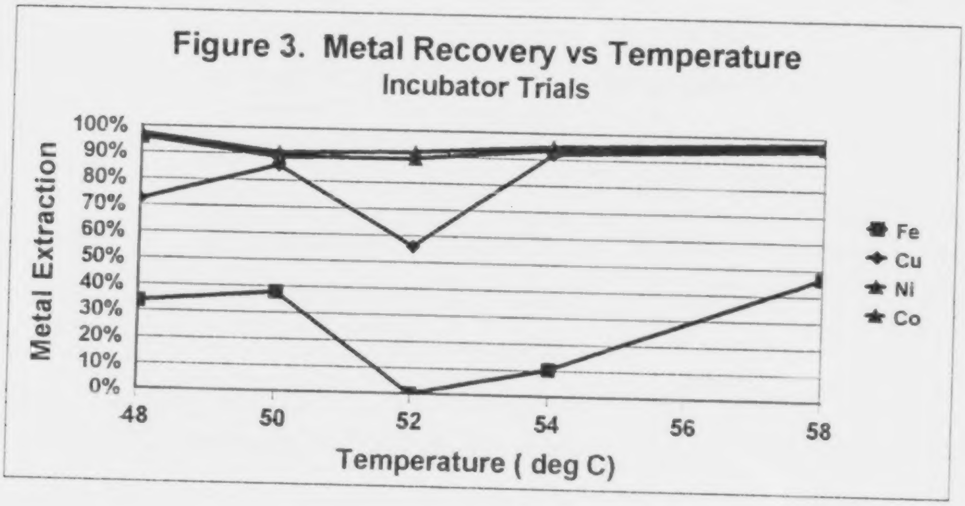


Figure 3. Metal Recovery vs Temperature
Incubator Trials

due primarily to bacterial action. As an example, we can examine the iron in NCSF25 (Series 5; Table G4) wherein the total iron increased from 4 gpl to 32 gpl during the 18 day test. Correspondingly, the ferric ion increased from 2 gpl to 20 gpl. This result supports a strong oxidation test, which was the best result for that series.

V.2.2.2 pH Effects. Metal extractions for the NCSF trials are calculated based on a head assay and the residue assays of the solids after the bacterial oxidation tests are terminated. The results are tabulated in Tables G6 to G15. The metal extractions as a function of pH are illustrated in Figure G1 to G3. The graphs on the effect of pH generally show a modest decline with increasing pH. The oxidation behavior as a function of pH is consistent with the INC trials in that the pH controls iron oxidation. Since this massive pyrrhotite material is 40% iron, lower pH's require higher acid addition to maintain the desired pH. Higher acid requirements translate into higher operating costs. Consequently, it is desirable to define the highest possible operating pH without sacrificing metal extraction. These trials support the selection of a pH=1.5 as a reasonable compromise between acid consumption and metal extraction.

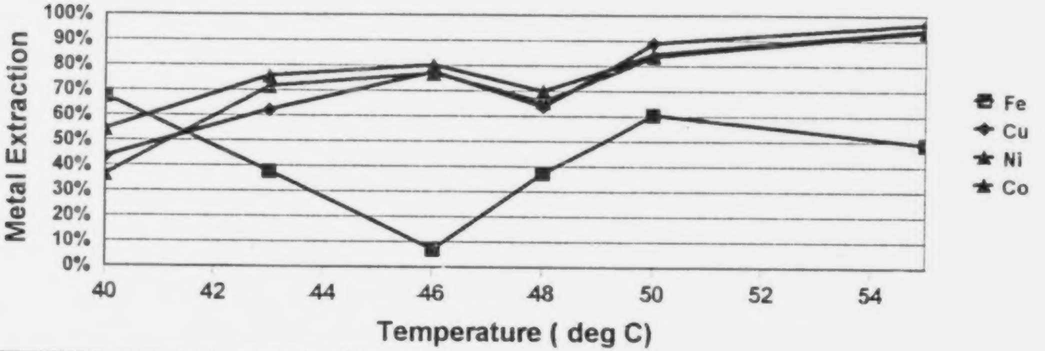
V.2.2.3. Temperature Effects. A number of the NCSF series were used to assess the effect of temperature. Initially, it was thought that there would be a maximum temperature at which point the oxidation rate would decline. The NCSF and INC trials have clearly demonstrated that bacterial oxidation activity is strong up to the maximum temperatures assessed. To establish this result, additional work and effort was required than foreseen in the original budget. It is clear that the bacterial population adjusts to the higher operating temperatures and some new species predominate at the higher temperatures. This would imply that a wide range of bacterial species are present at all times and populate according to the operating conditions, feed material, and available nutrients. The results from all the temperature tests are summarized in Table 3 and plotted in Figure 4. As seen in Figure 4, the metal recovery increases with increasing temperature but appears to go through a

Table 3. NCSF Metal Extraction Summary at Temperature and pH

| pH | Series 2 | Series 5 | Series 4 | Series 3 | Series 9 | Series 8 | |
|---|---|---|---|---|---|---|---|
| | 40 | 43 | 46 | 48 | 50 | 55 | |
| pH=1.5 | 67.48% | 37.68% | 7.14% | 37.14% | 60.49% | 48.84% | Fe |
| | 43.24% | 61.95% | 77.24% | 63.75% | 88.78% | 96.29% | Cu |
| | 54.14% | 75.59% | 79.97% | 69.81% | 84.39% | 94.07% | Ni |
| | 36.39% | 71.36% | 76.65% | 65.66% | 83.43% | 93.48% | Co |
| pH=1.2 | 80.49% | 56.02% | 27.23% | 44.56% | 63.34% | 55.59% | Fe |
| | 43.60% | 65.96% | 75.06% | 63.87% | 87.52% | 96.46% | Cu |
| | 47.91% | 78.94% | 81.26% | 66.32% | 92.14% | 94.64% | Ni |
| | 20.51% | 73.20% | 77.79% | 62.37% | 90.48% | 93.95% | Co |
| pH=1.8 | 61.89% | 33.31% | 15.53% | 37.61% | 48.34% | 44.47% | Fe |
| | 12.74% | 64.41% | 62.34% | 21.96% | 82.82% | 89.07% | Cu |
| | 30.59% | 71.97% | 72.84% | 45.68% | 85.45% | 84.00% | Ni |
| | 8.51% | 66.09% | 70.10% | 42.48% | 85.58% | 91.66% | Co |

Figure 4. NCSF - Temperature Trials

15% Solids; pH=1.5



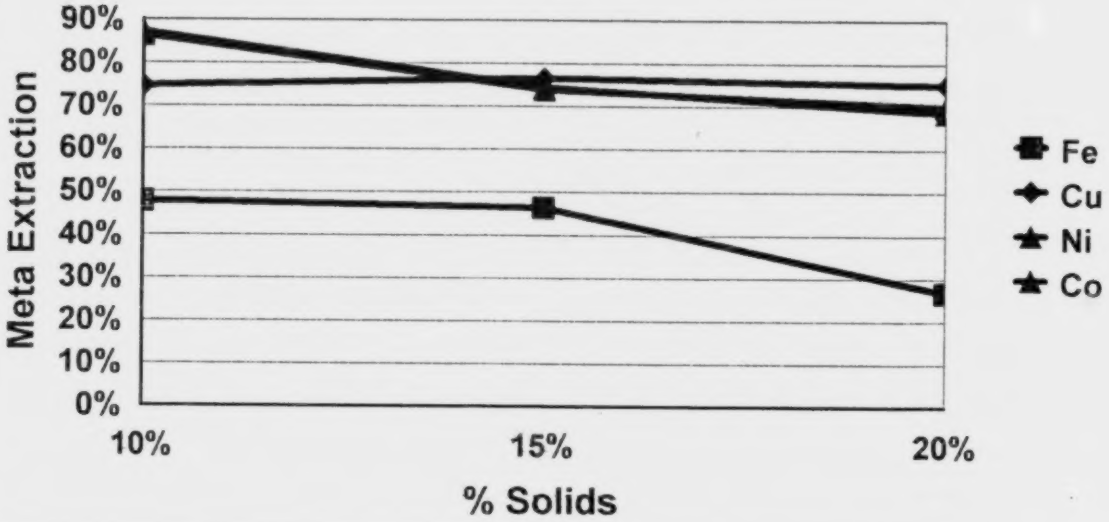
minimum at about 48°C. For example, recoveries at pH=1.2 were 96%, 95%, and 94% for Cu, Ni, and Co, respectively. These results are excellent since they were conducted at a 15% solids loading compared to similar results at 1% solids loading in the incubator trials. While the retention times for these tests are long, about 18-20 days, there is potential to optimize operating conditions to improve retention time and further increase temperatures. The bacterial oxidation process generates heat and the output from a commercial system based on this feed material would still require some cooling duty.

V.2.2.4 The Effect of Solids Loading. The Series 6 trials assessed the impact of solids loading. In commercial practice, solid loadings in excess of 20% represent a degree of technical difficulty and bacterial oxidation systems are usually designed for 20%. The results, illustrated in Figure 5, show a steady decline in metal recovery with increasing solids loading at a fixed pH, temperature, and retention time. This result is expected and shows that there is a design trade-off between lower retention times and higher solids loading. For example, higher solids loading mean a higher throughput for a given reactor volume while longer retention times require increased reactor volumes. Thus, the trade-off is one which compares capital and operating costs with additional revenue from higher recoveries.

V.2.2.5 The Effects of Initial Iron Loadings. The Series 7 trials assessed the impact of iron loading. Bacteria require some minimum concentration of sulphur as sulphide and iron in solution. The nutrient mix used to develop cultures contains essential nitrogen, phosphorous, and potassium but also contains iron. For example, the "10K" nutrient mix contains 10 gpl iron. For all the trials, a "0K" nutrient mix was used since the feed material is very high in iron and as the experiment proceeds the iron builds up very rapidly. In fact, high iron values of +40 gpl iron can have a negative impact on bacterial populations. In this series, illustrated in Figure 6, the results show that higher iron concentrations result in reduced iron oxidation and higher metal recovery in the range assessed. For stirred flask

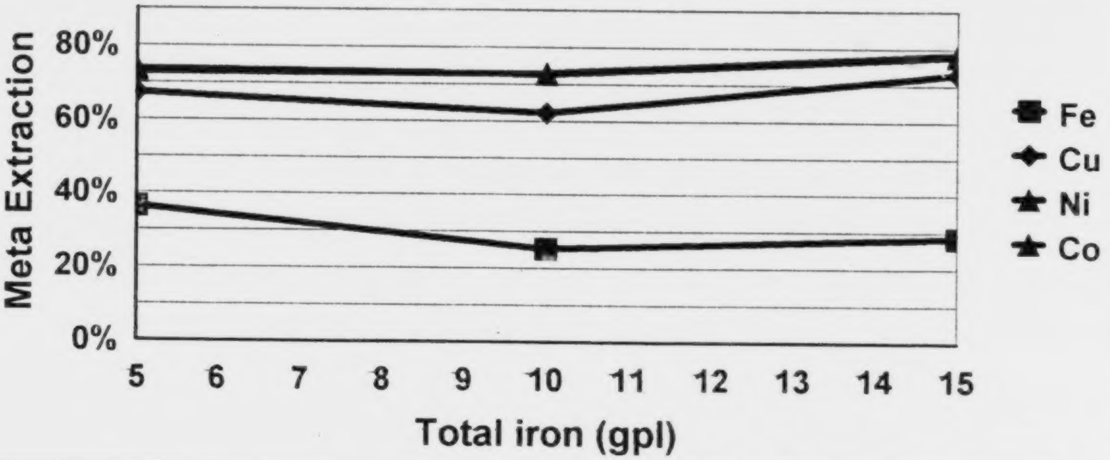
## Solids Loading vs Metal Extraction

Figure 5



## Iron Loading vs Metal Extraction

Figure 6



tests, higher initial iron loadings will yield improved metal recoveries. In a continuous system, the iron levels are considerable higher, generally about 20 gpl in the primary tanks.

V.2.2.6 Fresh Core - Series 10. A very preliminary test was conducted on fresh core material obtained from the recent drilling program. This material, as compared to the dump site samples used for the other NCSF trials, was relatively un-oxidized. Some problems were experienced in temperature control. Metal extraction was poor at all pH's, the highest nickel recovery being 31% at pH=1.2. Additional work is required to validate these trials but any further study should be done on concentrates prepared from the massive sulphide core material. It will also be useful to assess the mineral occurrences and non-oxidized minerals in the residues. Initial indications are that finer grinding will be required to improve performance.

V.2.2.7 Conclusions. The NCSF trials demonstrated that the bacterial oxidation process can be highly effective for the +90% recovery of nickel, cobalt, and copper from sulphide ore and with iron oxidation limited to <50%. The trials showed that higher oxidation rates and recoveries can be achieved at high temperatures, temperatures higher than those commonly used for these systems. In additional, there is an opportunity for improved rates at even higher temperatures. Additional testwork is recommended on concentrate feeds and on optimizing temperature, grind size, and nutrient loadings.

**V.3 CSTR Pilot Plant Trials**. The test conditions for these trials are summarized in the weekly log sheets (see Appendix C) which tabulate daily information. The CSTR trials were operated in two stages based on a retention time of 10 days and 15 days. Temperature was changed during the run and the pH was maintained at 1.5. The solids loading was 15% through the entire run. The Phase 1 CSTR trials were started on Sep 28, 1997 and were completed on Nov 27, 1997 for a total run time of 60 days. At Day 22, a portion of the Tank N3 overflow was recycled back to N1. The percent recycle was set to maintain an initial iron loading of 10 gpl. The

Phase 2 CSTR trials were started on Nov 28, 1997 and ended on Dec 19, 1997 for a total run time of 21 days.

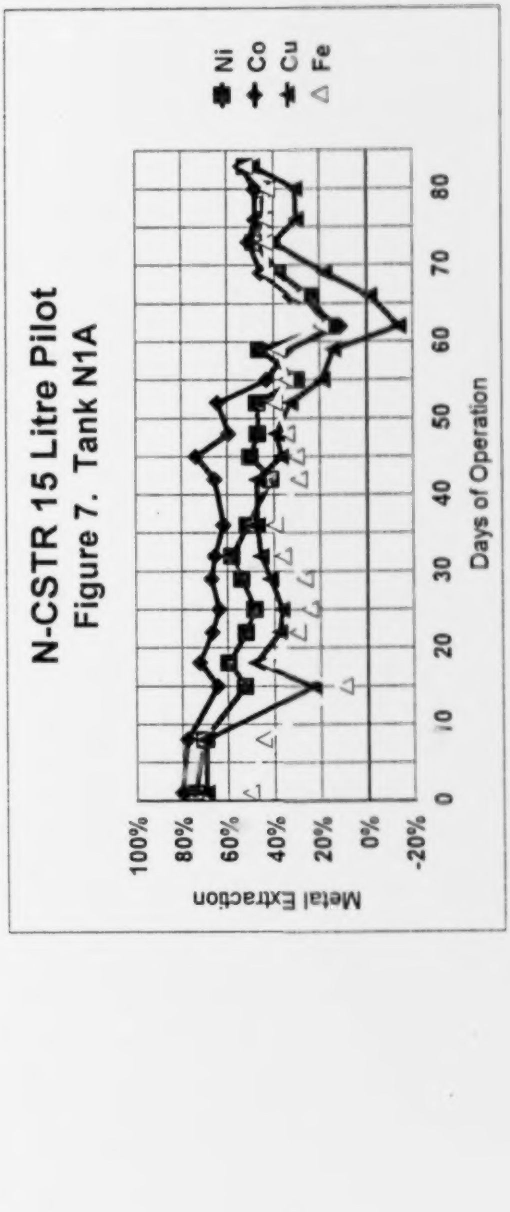
V.3.1. General. The progress of the pilot was followed by total iron and ferric ion loadings in solution. The titration data is summarized in Appendix H; Table H1 and plotted in Figures H1/H2 for Phase 1 and H3/H4 for Phase 2. The assessment of bacterial oxidation performance was made through elemental assays on tank residues. Twice weekly a 500 ml slurry sample was withdrawn from each tank and filtered. The solids were washed 2x and sent to TUNS for assay. The residue assays and calculation of metal recovery are tabled in Appendix H; Table H2 to H23. The Phase 1 trial was designed to establish operational mode, to train staff in operations, to identify any problem areas, to assess temperature effects and recycle at a 15% solids loading, a pH=1.5, and a retention time of 10 days. The Phase 2 program was designed to provide recovery data based on a 15% solids loading and a 15 day retention time. The metal extraction data is summarized in Table 4 for the entire pilot run and illustrated for each tank in Figures 7(Tank 1a), 8(Tank 1b), 9(Tank N2), and 9(Tank N3). Initially, the recovery in the primaries declined during the first 10d and behaved in a steady state fashion afterwards. A key transition point occurred after Day 50 at which point metal recovery plummeted in N1a. In contrast N1b maintained steady state performance. In the secondary tanks, performance declined at Day 60 which would indicate some negative impact arising from N1a. A shift to a longer retention time clearly gave an increase in metal recovery (Figure 10) with copper showing the strongest increases in extraction. In general, about 9%/d metal extraction (Ni) was achieved in the primaries with about 5%/d in the secondaries. Shifting to a 15d retention time gave a decrease to 3%/d extraction in the secondaries with the primaries being unchanged. Additional run time would be necessary to properly assess the changes in retention time. Table 4 also notes key event changes during the run. Of particular note is the recycle of solution at Day 22 and the increases in nitrogen addition on Day 36 and Day 60. Bacterial counts during the course of the pilot run showed at least three types of bacteria with declining populations during the course of the run.

## Table 4. CSTR - N Series 15L Pilot Plant Summary Results; Residue Assays

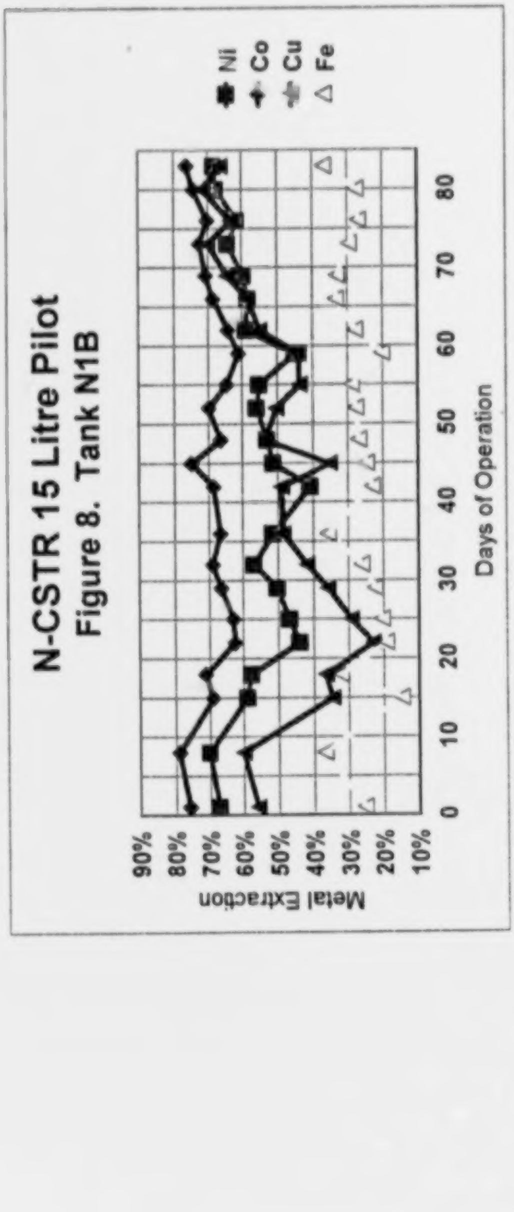
| Date | Days | Tank N1A | | | | Tank N1B | | | | Tank N2 | | | | Tank N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % Ni | %Co | %Cu | %Fe | % Ni | %Co | %Cu | %Fe | % Ni | %Co | %Cu | %Fe | % Ni | %Co | %Cu | %Fe |
| 29-Sep-97 | 1 | 74.6% | 80.5% | 69.6% | 50.5% | 67.2% | 76.0% | 56.0% | 25.7% | 65.0% | 97.5% | 51.8% | 9.1% | 75.3% | 98.3% | 66.0% | 28.5% |
| 06-Oct-97 | 8 | 70.5% | 77.8% | 69.6% | 45.1% | 70.3% | 79.0% | 60.2% | 37.1% | 76.3% | 83.0% | 71.7% | 37.6% | 79.3% | 86.1% | 76.9% | 40.6% |
| 13-Oct-97 | 15 | 53.0% | 64.6% | 23.3% | 10.0% | 59.1% | 69.1% | 34.8% | 15.1% | 72.9% | 80.5% | 66.4% | 38.9% | 77.7% | 84.6% | 72.2% | 46.2% |
| 16-Oct-97 | 18 | 60.0% | 72.4% | 48.2% | 44.0% | 57.9% | 71.2% | 36.8% | 32.4% | 69.4% | 78.1% | 61.1% | 40.2% | 76.1% | 83.0% | 67.5% | 51.7% |
| 20-Oct-97 | 22 | 52.3% | 66.8% | 37.9% | 30.2% | 44.1% | 62.5% | 23.1% | 19.4% | 57.5% | 70.7% | 46.6% | 26.8% | 65.5% | 75.6% | 53.9% | 30.9% |
| 23-Oct-97 | 25 | 48.5% | 63.8% | 36.9% | 24.8% | 46.9% | 62.9% | 29.5% | 20.4% | 61.5% | 72.1% | 51.7% | 24.1% | 66.8% | 75.9% | 54.9% | 36.8% |
| 27-Oct-97 | 29 | 54.1% | 67.2% | 41.9% | 26.9% | 50.5% | 66.5% | 36.0% | 22.5% | 59.2% | 71.5% | 51.0% | 23.1% | 67.6% | 76.8% | 57.3% | 36.1% |
| 30-Oct-97 | 32 | 58.5% | 65.7% | 45.8% | 36.1% | 57.1% | 69.0% | 42.0% | 26.3% | 66.7% | 74.5% | 60.2% | 37.8% | 73.7% | 79.1% | 62.2% | 40.4% |
| 03-Nov-97 | 36 | 51.5% | 61.8% | 47.5% | 40.0% | 51.6% | 66.6% | 48.6% | 35.9% | 69.5% | 75.8% | 66.9% | 49.2% | 75.0% | 79.7% | 69.6% | 49.9% |
| 06-Nov-97 | 42 | 41.6% | 65.6% | 47.4% | 29.1% | 40.9% | 68.5% | 48.9% | 23.2% | 56.7% | 76.1% | 62.9% | 39.8% | 69.4% | 83.1% | 72.0% | 46.9% |
| 10-Nov-97 | 45 | 50.4% | 73.9% | 37.0% | 30.3% | 51.4% | 75.1% | 35.4% | 24.7% | 69.4% | 84.0% | 63.8% | 49.2% | 74.4% | 86.7% | 68.8% | 59.0% |
| 13-Nov-97 | 48 | 47.2% | 59.6% | 39.1% | 34.5% | 53.1% | 66.4% | 53.4% | 27.0% | 67.6% | 77.2% | 71.6% | 46.3% | 76.5% | 83.2% | 76.3% | 52.7% |
| 17-Nov-97 | 52 | 47.3% | 64.4% | 32.9% | 40.0% | 56.1% | 69.9% | 50.3% | 27.7% | 63.7% | 74.1% | 59.6% | 47.4% | 77.1% | 82.9% | 73.9% | 54.7% |
| 20-Nov-97 | 55 | 30.1% | 43.5% | 19.0% | 34.3% | 55.1% | 64.6% | 43.8% | 29.0% | 62.7% | 74.7% | 64.2% | 44.4% | 68.0% | 82.9% | 74.7% | 51.5% |
| 24-Nov-97 | 59 | 46.4% | 34.4% | 14.3% | 38.5% | 45.1% | 61.2% | 44.2% | 20.1% | 61.0% | 72.4% | 59.9% | 34.1% | 76.6% | 76.3% | 71.0% | 49.1% |
| 27-Nov-97 | 62 | 15.3% | 11.3% | -13.7% | 19.4% | 59.0% | 64.1% | 55.0% | 27.9% | 59.8% | 64.4% | 59.3% | 34.3% | 68.6% | 71.0% | 72.3% | 45.2% |
| 01-Dec-97 | 66 | 24.5% | 33.0% | -1.2% | 29.8% | 58.5% | 68.6% | 58.4% | 33.3% | 64.6% | 71.6% | 70.2% | 41.1% | 67.7% | 72.5% | 76.0% | 53.0% |
| 04-Dec-97 | 69 | 38.1% | 45.7% | 18.2% | 43.2% | 59.8% | 70.8% | 64.5% | 33.1% | 70.8% | 78.4% | 76.1% | 43.0% | 76.2% | 82.4% | 80.1% | 43.6% |
| 08-Dec-97 | 73 | 48.6% | 50.8% | 40.7% | 43.6% | 64.3% | 72.6% | 70.2% | 29.6% | 75.9% | 80.2% | 77.7% | 45.3% | 80.4% | 84.2% | 80.9% | 44.3% |
| 11-Dec-97 | 76 | 44.5% | 47.9% | 30.1% | 43.6% | 61.6% | 70.2% | 63.3% | 26.9% | 73.8% | 79.1% | 73.6% | 45.7% | 84.3% | 87.1% | 82.2% | 46.3% |
| 15-Dec-97 | 80 | 45.2% | 48.3% | 30.6% | 42.8% | 67.8% | 74.3% | 71.9% | 27.7% | 65.5% | 71.4% | 64.0% | 29.0% | 84.0% | 87.0% | 80.5% | 41.5% |
| 18-Dec-97 | 83 | 52.1% | 54.0% | 49.1% | 52.2% | 68.4% | 76.3% | 66.2% | 36.9% | 75.2% | 80.6% | 78.3% | 37.8% | 84.8% | 87.9% | 81.5% | 44.4% |

**Notes:**

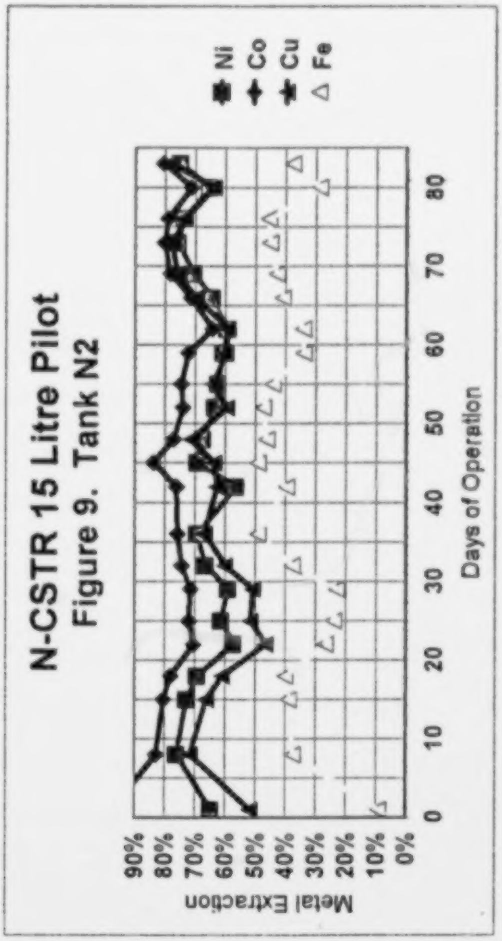
Day 01: Retention Time set at 10d; pH=1.5; T=50 degC; "OK" Nutrient
Day 15: N3 solution changed from dark green to brown
Day 22: Recycle started
Day 29: N1A - 7M Counts (3 different sizes of rods)
Day 36: N addition doubled (30 to 60g/10l)
Day 36: N1-750K;N2-3M Counts (small and medium rods + leptospirilium)
Day 37: 4 litres N1a exchanged for water to lower iron concentration
Day 49: N1A-170K;N1B-450K Counts (small and medium rods)
Day 61: N1A-300K;N1B-240K Counts (small and medium rods;some bugs)
Day 60: "N" addition increased to 90g/10L; other nutrients doubled
Day 60: Retention Time increased to 15d (Day 60)
Day 83: Pilot Stopped



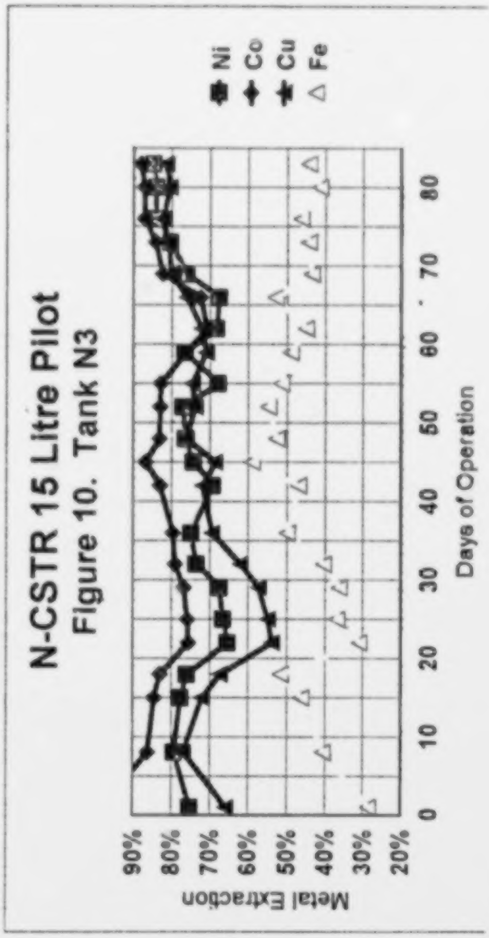
N-CSTR 15 Litre Pilot
Figure 7. Tank N1A



N-CSTR 15 Litre Pilot
Figure 8. Tank N1B



N-CSTR 15 Litre Pilot
Figure 9. Tank N2



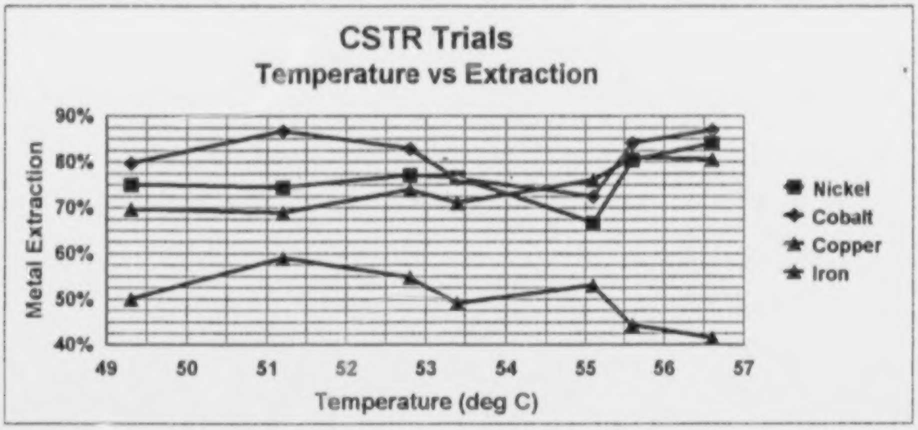
N-CSTR 15 Litre Pilot
Figure 10. Tank N3

V.3.2 Comportment of Iron. In the 1st Phase of the trials, total iron (Figure H1) increased steadily, averaging from 28 gpl to 46 gpl, in all tanks up to about Day 44 and then decreased marginally. The ferric ion levels (Figure H2) were more erratic but increased from about 10-12 gpl to greater than 20 gpl. During the run, at Day 15, the Tank N3 overflow (O/F) solution changed from a dark green to brown indicative of the stronger ferric ion concentrations. Periodically, Tank N2 also changed to a brown colour. This effect is a strong indication of the bacterial oxidation of ferrous ion to ferric ion. In the 2nd Phase represented in Figures H3/H4 for total iron and ferric ion, respectively, a clear distinction can be made between Tank N1a and the others. The total iron values were very high and required adjustment. Approximately 4 liters of N1a solution was removed and replaced with acid mine water at Day 9 (Day 69 in Table 4). The iron titration results are variable and not easily re-produced. They are designed to indicate trends in bacterial oxidation behaviour and to signal operational problems. In general, the higher the total iron the higher the ferric ion which would indicate that there are some interferences especially at the higher levels. The decline in the performance of Tank N1a was attributed, in part, to the high iron. This was corrected by dilution and stricter control on iron loadings in the recycle solution.

V.3.3 Temperature Effects. The pilot trial was held in steady state condition with respect to temperature, approximately 49°C, up to Day 25. At that time, it was clear that increased oxidation rates would be required to meet target metal recoveries. The temperature was then increased in small increments over the remainder of the pilot trials to minimize the impact on the bacterial populations. The NCSF and INC trials had demonstrated improved recoveries at higher temperatures. The change in temperature was the major process variable assessed in this program. The performance trends as a function of temperature are summarized in Table 5 and in the associated figure. As the temperature increased, the iron oxidation decreased from a high of 59% to a low of 42%. Concurrently, the copper increased from a low of 69% to a high of 81%. Nickel and cobalt recoveries attained their maximum values of 84% and 87%, respectively, at 56.6°C. The strong correlation between nickel and cobalt extraction at the higher temperatures is significant. It is also worth noting that the there is a minimum around 55°C which is considered

## Table 5. Temperature Trends in CSTR Trials

| | | | Metal Extraction | | |
|---|---|---|---|---|---|
| Date | Deg C | Nickel | Cobalt | Copper | Iron |
| 03-Nov-97 | 49.3 | 75.01% | 79.70% | 69.58% | 49.90% |
| 10-Nov-97 | 51.2 | 74.41% | 86.71% | 68.85% | 59.00% |
| 17-Nov-97 | 52.8 | 77.14% | 82.92% | 73.89% | 54.75% |
| 24-Nov-97 | 53.4 | 76.58% | 76.30% | 71.03% | 49.11% |
| 01-Dec-97 | 55.1 | 66.70% | 72.50% | 76.00% | 53.00% |
| 08-Dec-97 | 55.6 | 80.40% | 84.20% | 80.90% | 44.30% |
| 15-Dec-97 | 56.6 | 84.00% | 87.00% | 80.50% | 41.50% |



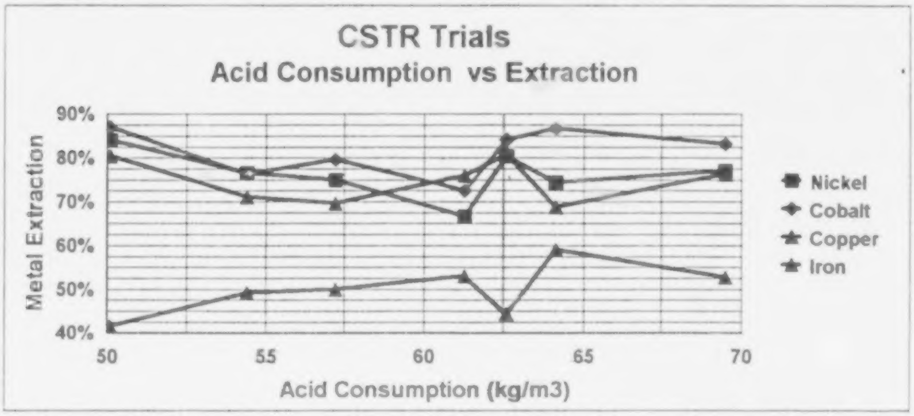
the high end range for moderate thermophiles. This minimum would suggest that there is some shift in the bacterial population in the CSTR.

V.3.4 Acid Consumption. Acid consumption is a critical factor in any process that involves the oxidation of a pyrrhotite based ore. In general, these ores consume large quantities of acid during oxidation and can result in excessive operating costs and render a project uneconomic. Between Day 36 and Day 80, the trend in acid consumption as a function of metal extraction was assessed. The results are summarized in Table 6 and its associated figure. As seen in the table, the highest metal extraction (e.g. oxidation) does not correlate with a high acid consumption. This relates, in part, to the lower iron oxidation observed at the higher temperatures as cited above. Acid consumption over this period ranged from a low of 50 kg/m$^3$ of process solution to a high of 69.5 kg/m$^3$. Values less than 100 kg/m$^3$ are relatively low and provide some flexibility to decrease pH. Lower pH's at values <1.2 usually give rise to higher recoveries and this was seen in the NCSF trials. The CSTR trials were operated at a pH=1.5 to keep acid consumption low.

V.3.5 Nutrients and Bacterial Populations. A standard "0"K nutrient mix was used up to Day 36. On Day 25, samples were taken for nitrogen assays and the results are summarized in Table 7. As a consequence of the low nitrogen values, corrective action which comprised doubling the nitrogen from 3 to 6 gpl of ammonium sulphate was taken on Day 36. The ammonium sulphate loading was increased to 9 gpl on Day 60. As seen in the table, the increased additions did give improvements in the loading in Tank N1b but were still low in N2 and N3. The higher levels in N1a at Day 72 would suggest that the uptake by the bacterial population is poor and would correlate with the poor performance of this tank that was noted previously. Insufficient CSTR run time was available to properly optimize nutrient loadings and, thus, additional work is required in this area. Bacterial counts were cited in Table 4 and it is noted that bacterial populations were strong at Day 25. By Day 48, counts had dropped to less than 1 million. Levels were slightly improved at Day 59. No further counts were taken but from the improved metal recovery at the end of the trial, one would conclude that populations have increased. Further work is required at

- Table 6. Acid Consumption Trends in CSTR Trials

| Date | Acid kg/m3 | Metal Extraction | | | |
|---|---|---|---|---|---|
| | | Nickel | Cobalt | Copper | Iron |
| 15-Dec-97 | 50.1 | 84.00% | 87.00% | 80.50% | 41.50% |
| 24-Nov-97 | 54.4 | 76.58% | 76.30% | 71.03% | 49.11% |
| 03-Nov-97 | 57.2 | 75.01% | 79.70% | 69.58% | 49.90% |
| 01-Dec-97 | 61.3 | 66.70% | 72.50% | 76.00% | 53.00% |
| 08-Dec-97 | 62.6 | 80.40% | 84.20% | 80.90% | 44.30% |
| 10-Nov-97 | 64.1 | 74.41% | 86.71% | 68.85% | 59.00% |
| 17-Nov-97 | 69.5 | 77.14% | 83.21% | 76.25% | 52.71% |



the higher temperatures which would require a minimum of 30 days of continuous operation which was not possible in this program.

**Table 7. CSTR Trials - Nitrogen Assays (mg/L)**

| Day | Tank 1a | Tank 1b | Tank 2 | Tank 3 |
|---|---|---|---|---|
| 25 | 38.5 | 18.5 | 17 | 3 |
| 37 | 170/189 | | | |
| 72 | 1140 | 210 | <50 | <50 |

V.3.6 Conclusions. The CSTR pilot trials demonstrated that the bacterial oxidation process can oxidize a pyrrhotite based concentrate with recoveries of nickel, cobalt, and copper approaching 90% at a retention time of 15 days, a pH=1.5, and a temperature of +56°C. Additional work on optimizing retention time, pH, temperature, grind size, and nutrient loadings will give rise to significant process improvements. At this stage, it is clear that a retention time of 15 days is required to achieve an average +90% metal extraction. Test results from the NCSF trials support higher metal extractions at higher temperature and lower pH. Due to low nitrogen levels, bacterial populations are not optimized and this effect will result in lower overall recoveries. However, it is essential that further CSTR studies be carried out on non-oxidized, more representative concentrate samples. Some of the positive benefits from the current study include the development of a thermophile culture, and the preliminary optimization of the major process variables.

**V.4. Metal Recovery and Flowsheet Development**. A series of preliminary tests were carried out on bioleach overflow solution obtained from the CSTR pilot trials to assess the best flowsheet options. No work has been done on metal recovery with respect to final product beyond the definition of product value that will be described in a section on market below. Nonetheless, metal recovery will be primarily directed to solvent extraction (SX). This technology is well understood for nickel and cobalt recovery and will be developed at a later date. Large volumes of bioleach solution that is representative of a commercial stream are necessary to carry out a comprehensive program on SX recovery and product definition. A CSTR pilot program on a properly defined concentrate operating under equilibrium optimized conditions for up to 60 days would be required for an SX test program.

V.4.1 General. An essential process step in the recovery of value added products from a bacterial oxidation process is iron control. The process generates a high ferric ion/total iron solution containing the economic metals of interest. Conventional iron treatments result in excessive metal losses and SX systems are not selective in the presence of ferric ion. For example, ferric ion will co-extract with most other metals. The ideal strategy is to reduce ferric ion to ferrous ion without any metal losses followed by SX and purification. This strategy will form part of the flowsheet discussion below.

V.4.2 Preliminary Trials. A series of preliminary scoping trials were carried out on bioleach solution to assess potential flowsheet options. The test protocols are defined in Tables D1/D2 (Appendix D) and the test results are found in Table D3 and in Figures D1 and D2. Tests NT1 and NT4 compared the degree of oxidized material present in the TUNS concentrate used for the CSTR trials and the fresh material obtained in core from the recent drilling program, respectively. It was found that 25% of the nickel/cobalt is easily oxidized relative to the fresh material. The other tests focused on two types of reactions, namely, precipitation and ferric reduction.

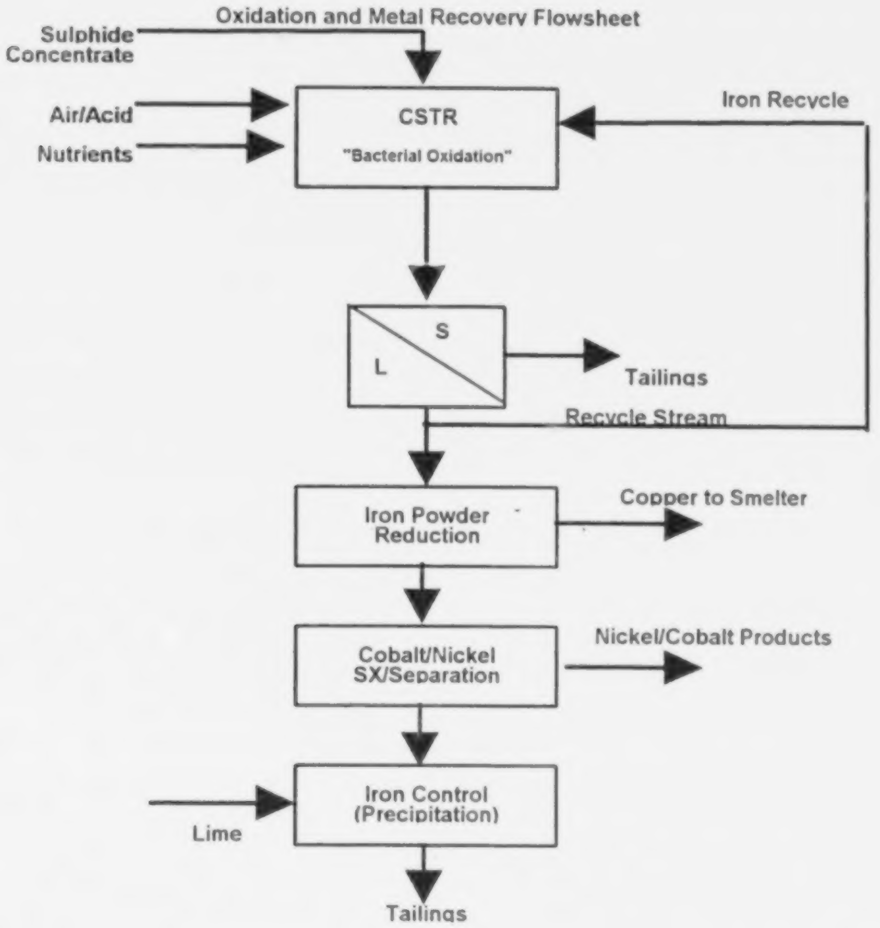
1.0 Precipitation. This effect was assessed using lime and sodium sulphide. In the lime test (NT3), it was observed that 94% of the copper could be removed at a pH <3.8 with losses of 6% nickel and 2% copper. Better pH control and optimization of operating conditions could minimize nickel and cobalt losses. The $Na_2S$ test (NT6) showed no selectivity and nearly all the metal was removed with very little iron loss. Dependent on operating cost, this may be an efficient means to separate the economic metals from iron followed by a small oxidation step.

2.0 Ferric Reduction. The use of fresh ore or concentrate as a reductant is a cheap method and also acts as a pre-leach for the material to be treated by the bacterial oxidation process. The first test (NT2) was not effective in reducing the ferric ion concentration. This led to a repeat test (NT5) at higher temperatures (+85°C). In this test, the ferric ion concentration was reduced by almost 50%. Further work will be required to optimize the reduction but the test demonstrates that reduction by this method is technically feasible.

V.4.5 Flowsheet. A preliminary flowsheet has been developed for the bacterial oxidation process (see Figure 11). The 6 CSTR tanks would comprise 3 primaries and 3 secondaries and would require a supply of air, nutrients, and acid. The flowsheet is based on the removal of copper as a mud using iron as a reductant and includes an iron recycle stream which returns ferric ion and bacteria back to the primary tanks. The solution from the iron step would go directly to a 2-stage SX circuit which would separate nickel/cobalt from iron followed by nickel/cobalt separation. This approach would yield highly pure nickel and cobalt sulphate solutions for processing to value added products. Once the iron control step is optimized and properly validated and sufficient SX feed solution is available, the preparation of value added products for marketing assessment and demonstration purposes can be completed.

V.4.6 Conclusions. A relatively simple flowsheet can be constructed based on St. Stephen Nickel Mine ore/concentrate. The flowsheet design is focused on iron reduction with the production of a low grade copper product. The solution produced in this manner can be effectively purified by SX and there are few, if any, impurities in the system. Final iron rich solutions can be safely limed and disposed by conventional means. It is expected that these steps will result in an overall loss in metals of about 10%. The key feature of a flowsheet for treating solution from a bacterial oxidation process is ferric ion control to ensure good selectivity in the SX step.

Figure 11. Direct Bacterial Oxidation for St. Stephen Nickel Mines


Oxidation and Metal Recovery Flowsheet
Sulphide Concentrate
Air/Acid
Nutrients
CSTR
"Bacterial Oxidation"
Iron Recycle
S
L
Tailings
Recycle Stream
Iron Powder Reduction
Copper to Smelter
Cobalt/Nickel SX/Separation
Nickel/Cobalt Products
Lime
Iron Control (Precipitation)
Tailings

## V.5 Preliminary Engineering and Process Economics.

V.5.1 General. Most of the unit processes for a commercial plant have been established for commercial operations elsewhere. Initial calculations have been based on contract mining and milling. The bacterial oxidation economics will be discussed separately below. Based on the information in hand at the moment, a preliminary analysis has been developed for the mine in Table 8. An overview of the mine analysis in the table is summarized as follows:

1. Ore Reserves. A conservative ore reserve calculation has been made. It is conservative since cobalt grades have been estimated in some cases for lack of assay data and additional drilling will increase the ore reserves. In this analysis, the tonnage has been calculated to be 642,563 tonnes at a grade of 0.869% Ni, 0.069% Co, and 0.412% Cu.

2. Operating Costs. The total processing costs of $90/tonne is conservative. Some reduction in the mining costs of $50/tonne may be made once negotiations are carried out with a contractor.

3. Concentrates. In this preliminary model, all the ore is processed to a concentrate which goes to a bioleach plant. A 127 tpd bioleach plant is quite large and a smaller plant of the order of 50 tpd may be used concurrent to the production of a high grade concentrate for sale to a smelter. This option is currently being evaluated by the company. The flotation data used for this analysis was taken from Table 2 based on work done on fresh core obtained from the open pit material.

4. Metal Pricing and Product Value. The revenue from the commercial plant is based on value added mineral products using the factors of 150% for Ni, 200% for Co, and 100% for Cu. A complete description is discussed in the following section.

**Table 8. St. Stephen Nickel Mines Plan at a Production Rate of** 379 tpd
**Product Value Analysis for Mine** 128,996 tpy

| | Grade | kg/Ton | Metal tpy | US Price/lb | Flotation Recovery | Process Recovery | Product Value(avg.) | Market Value | Ore Value |
|---|---|---|---|---|---|---|---|---|---|
| Nickel | 0.869% | 8.69 | 736 | $7.70 | 77% | 85% | 150% | $65.88 | $66.89 |
| Cobalt | 0.069% | 0.69 | 67 | $33.00 | 88% | 85% | 200% | $34.28 | $22.85 |
| Copper | 0.412% | 4.12 | 410 | $2.42 | 91% | 85% | 100% | $7.69 | $9.96 |
| | | | | | | | | $0.00 | $0.00 |
| | | | | | | | | $107.85 | $99.70 |

| | | | | |
|---|---|---|---|---|
| Reserve = | 642,563 | Tons of "indicated" and "inferred" | | |
| Years of Operation = | 5.0 | | Days of Operation per year = 340 | |
| $US per Ton of Ore = | $99.70 | C$132.94 | | |
| $US Revenue per Ton of Ore = | $107.85 | C$143.79 | | |
| Estimated Mass Recovery from Flotation = | | | 36% (2.79) | |
| Nickel Grade in Concentrate = | | 3.09% | 875 | TPY |
| Cobalt Grade in Concentrate = | | 0.24% | 79 | TPY |
| Copper Grade in Concentrate = | | 1.82% | 539 | TPY |
| Concentrate Feed Rate = | 126.8 TPD | | 379.4 | TPD Ore |

| Operating Cost Estimates @ | 379.4 | tpd | Annual Costs |
|---|---|---|---|
| Mining Costs | $50.00 | /tonne | $6,450,000 |
| Milling Costs | $15.00 | /tonne | $1,935,000 |
| Process Plant | $20.00 | /tonne | $2,580,000 |
| Maintenance | $1.10 | /tonne | $141,900 |
| Laboratory | $2.00 | /tonne | $258,000 |
| Management | $2.00 | /tonne | $258,000 |
| Total Processing Cost = | $90.10 | /tonne | $11,622,900 |
| | | | |
| Monthly Operating Cost | $968,575 | | $11,622,900 |
| Monthly Revenue | $1,545,779 | | $18,549,343 |
| Monthly Margin | $577,204 | | $6,926,443 |
| Annual Margin | $6,926,443 | | |
| US Exchange Rate = | 1.33 | | |

**Reserve Calculations:**

| Category | Tonnage | % Ni | % Co | %Cu |
|---|---|---|---|---|
| Proven-Open Pit-Farm | 119,000 | 1.316% | 0.112% | 0.638% |
| Proven(A1+A2)-Farm | 201,300 | 1.045% | 0.087% | 0.437% |
| Indicated(B)-Farm | 89,900 | 0.650% | 0.060% | 0.370% |
| Inferred(A2+B)-Farm | 112,700 | 0.700% | 0.060% | 0.360% |
| Indicated-Hall/Carroll | 125,000 | 0.960% | 0.060% | 0.490% |
| Indicated-"C" | 38,333 | 0.830% | 0.050% | 0.340% |
| Total/Average Grade | 686,233 | 0.985% | 0.077% | 0.457% |
| Extraction | 584,148 | | | |
| Diluted Grade | 642,563 | 0.869% | 0.069% | 0.412% |
| Percent Dilution | 10% | | | |
| Percent Extraction | 85% | | | |

*Note: Open Pit Material 100% extraction* 5.0 Total Years

**Product Value Analysis**

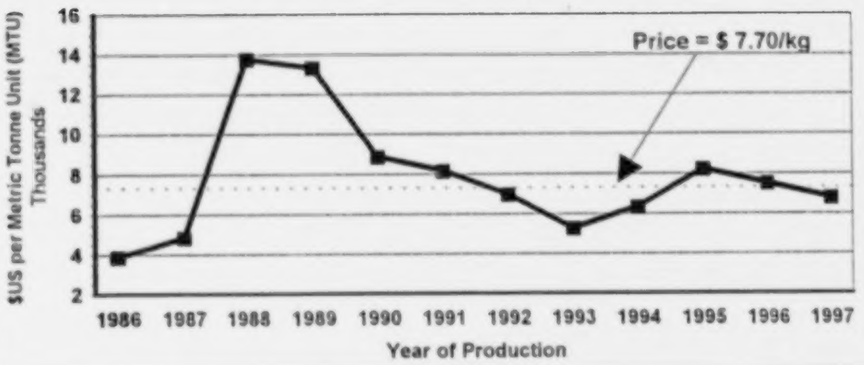
| High | Low | Average | |
|---|---|---|---|
| 225% | 75% | 150% | Ni |
| 325% | 75% | 200% | Co |
| 125% | 75% | 100% | Cu |

Note:
1. A high value is based on value-add chemicals
2. A low value is based on metal product

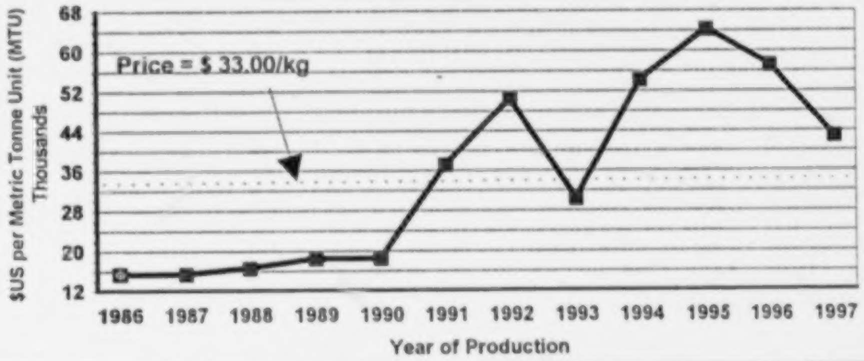
V.5.2 Metal Prices and Upgraded Products. The bacterial oxidation process generates metal sulphates in solution. Conventional processes involve the production of metal and the preparation of value added chemicals from the metal product. The use of this process permits the use of an alternative processing concept whereby the metal sulphates in solution are purified and converted to value added materials. To establish the impact of this approach on the process economics, it has been necessary to track the relevant metal prices over a 10 year span and set a metal price with which revenues from a commercial plant can be calculated (see Figure 12). As well, an assessment was made on prices of various metal products that could be produced easily from metal sulphate solution. In Table 9, the various potential products are identified along with current pricing obtained from the Chemical Marketing Reporter. The ore value per tonne is calculated based on the pricing data in Table 8 and Figure 12. On average value added products can yield twice the revenue compared to metal.

V.5.3 Process Economics. A preliminary assessment of the capital and operating costs was carried out for the St. Stephen Nickel Mine based on 150,000 tonnes per year (tpy) of ore over 5 years having a head grade of 0.95% Ni, 0.09% Co, and 0.47% Cu. This assessment, tabled in Appendix E, shows ROE (return on equity) of 26.1%. It is based on a number of assumptions which include the processing of a concentrate by a bacterial leach process to value added chemicals. The flotation recoveries used were 70% Ni, 80% Co, and 82% Cu which are considered low compared to recent test data and improvements that will made once better grind control is achieved and locked cycle information is available. Factors of 150%, 200%, and 100% were used for Ni, Co, and Cu, respectively, to establish product pricing. It has been assumed that contract mining and milling will be used with capital allocated for a bacterial oxidation plant and metal recovery at about $10 Million. Very conservative pricing has been established for operating costs. In general, the assumptions made were reasonable and quite conservative in some cases and the calculated ROE will be a minimum return. Metal and product pricing and the other assumptions used for this preliminary economic analysis are cited in Table 8.

### Figure 12a. Nickel Metal Price



### Figure 12b. Cobalt Metal Price



### Figure 12c. Copper Metal Price

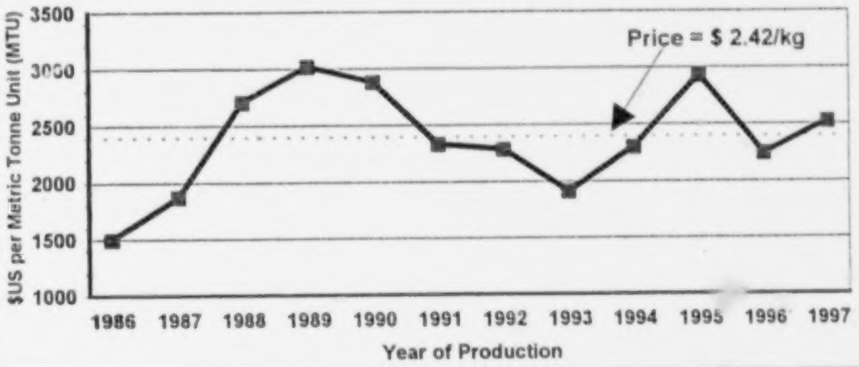


Table 9. Ore Value per Tonne with Value-Added Mineral Products

| Metal | Mineral Product | Product Factor | Price $US/kg | Flotation Recovery | Process Recovery | Ore Grade | Metal Value/Tonne | | Ore Value/T |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $US | $CDN | |
| | **Sulphates** | | | | | | | | |
| Ni | NiSO4.6H2O | 4.48 | $5.13 | 77% | 85% | 0.87% | $130.55 | C$174.07 | |
| Co | CoSO4.6H2O | 4.46 | $17.95 | 88% | 85% | 0.07% | $41.36 | C$55.15 | C$250.52 |
| Cu | CuSO4.5H2O | 3.93 | $1.28 | 91% | 85% | 0.41% | $15.98 | C$21.30 | |
| | **Acetates** | | | | | | | | |
| Ni | Ni(C2H3O2)2 | 3.01 | $5.92 | 77% | 85% | 0.87% | $101.37 | C$135.16 | |
| Co | Co(C2H3O2)2 | 3.00 | $21.52 | 88% | 85% | 0.07% | $33.36 | C$44.48 | C$253.06 |
| Cu | Cu(C2H3O2)2.H2O | 3.14 | $5.50 | 91% | 85% | 0.41% | $55.07 | C$73.42 | |
| | **Nitrates** | | | | | | | | |
| Ni | Ni(NO3)2.6H2O | 4.95 | $4.33 | 77% | 85% | 0.87% | $122.12 | C$162.82 | |
| Co | Co(NO3)2.6H2O | 4.94 | $17.51 | 88% | 85% | 0.07% | $44.63 | C$59.51 | C$268.54 |
| Cu | Cu(NO3)2.3H2O | 3.80 | $2.86 | 91% | 85% | 0.41% | $34.65 | C$46.20 | |
| | **Carbonates** | | | | | | | | |
| Ni | NiCO3 | 2.02 | $9.61 | 77% | 85% | 0.87% | $110.58 | C$147.44 | |
| Co | CoCO3 | 2.02 | $40.41 | 88% | 85% | 0.07% | $42.10 | C$56.13 | C$229.56 |
| Cu | CuCO3 | 1.94 | $3.15 | 91% | 85% | 0.41% | $19.49 | C$25.99 | |
| | | | | | | | | | |
| Ni | | 1.00 | $7.70 | 100% | 100% | 0.87% | $66.91 | C$89.22 | |
| Co | | 1.00 | $33.00 | 100% | 100% | 0.07% | $22.77 | C$30.36 | C$132.87 |
| Cu | | 1.00 | $2.42 | 100% | 100% | 0.41% | $9.97 | C$13.29 | |
| | | | | | | Average Value-Added/Tonne = | | | C$250.42 |

**Notes:**
1. "Product Factor" adjusts for % Metal in Product
2. Prices taken from Chemical Marketing Reporter - May, 1997
3. US Conversion Rate = 1.33

V.5.4 Bacterial Oxidation Plant. A preliminary model has been developed for the bacterial oxidation process but requires more process data before it can be finalized. The capital cost of a bacterial oxidation plant is primarily related to tank size. From other commercial operations, it has been estimated that the capital cost of a plant that contains 6 - 945 $m^3$ tanks is approximately $5 million. For comparison, the following data has been calculated for the St. Stephen Nickel Mine:

| Tonnage | Retention Time | Solids Loading | Tank Volume |
|---|---|---|---|
| 129,000 tonnes | 15 days | 15% | 1,953 $m^3$ |
| 129,000 tonnes | 15 days | 20% | 1,410 $m^3$ |
| 129,000 tonnes | 10 days | 15% | 1,304 $m^3$ |
| 129,000 tonnes | 10 days | 20% | 942 $m^3$ |
| 64,500 tonnes | 15 days | 15% | 979 $m^3$ |
| 64,500 tonnes | 15 days | 20% | 708 $m^3$ |
| 64,500 tonnes | 10 days | 15% | 655 $m^3$ |
| 64,500 tonnes | 10 days | 20% | 474 $m^3$ |

The data shows the impact of retention time and solids loading on reactor size. The test work carried out to date has validated 15% solids loading and 15 days retention time. Experience with these systems has shown that a solids loading of 20% is technically feasible. The major technical hurdle at this stage is related to retention time for a 129,000 tpd operation. For capital cost and technical reasons, it is necessary to optimize the process such that the retention time is less than 10 days. Under this condition, the reactor size will be about 950 $m^3$ and for a smaller operation about 450 $m^3$. Systems of this scale are being operated on a commercial basis today.

V.5.5 Conclusions. Additional technical data is required to complete the engineering and economic analysis. This could be done through a demonstration plant program which would validate all technical aspects of the process and generate a bankable document for financing. The preliminary economics are positive and indicate an excellent return on investment.

## VI. Conclusions and Recommendations

Conclusions have been made for each of the major project activities. In a more general context, the scope of the technical programs was changed to address the higher priority items.

Flotation. There is a need to further develop and optimize a flotation reagent scheme and operating conditions to produce a concentrate. The initial test work has been very positive and has identified areas for further evaluation. Specifically, areas for study include the definition of the nature of the nickel losses, the optimization of recoveries through locked cycle trials, the definition of optimum grind size with fresh sulphide material and a scaled demonstration flotation project.

Bacterial Oxidation Process. The program validated the technology as a viable means to recover nickel, cobalt, and copper. The process still requires optimization particularly at higher temperature and lower pH to further reduce retention times. Nutrient loadings need to be optimized. All this work should be carried out at a pilot scale on concentrate made from fresh material. If possible, the work should be carried out in 8-10 $m^3$ tanks.

Flowsheet Development. While general principles have been defined for metal recovery, it is important that future test work be carried out on material that is representative of a potential commercial scenario. To do this, the resource must be further defined and a bulk sample needs to be evaluated.

Process Economics. Preliminary estimates on capital and operating costs show a positive return, +25%, for the commercial venture. More specific engineering data is required for a bankable document which will be a prerequisite for commercial financing. A fully integrated demonstration plant trial is required to generate this data.

# VII. References

1.0 "Pre-Feasibility Study on the Opening of the St. Stephen Nickel Mine", a Technical Project Proposal by DRD Services Inc., DRDP/97/01, February, 1997

2.0 RPC Report " " by Richard May, 1988

# Appendix A

## Flotation Trials

## Minerals Associates/Lakefield Research

MINERALS ASSOCIATES

SUMMARY REPORT

# MINERAL PROCESSING TESTWORK

# BULK CONCENTRATE FLOWSHEET
for
ST STEPHEN CU/NI/CO

prepared for
DRD SERVICES INC

April 7, 1997

PROJECT # 026
ROBERT SALTER, Ph. D., P. Eng.
PROJECT MANAGER

850 Water Street Peterborough ON Canada K9H 3N9 Ph 705-749-6761 Fax 705-749-9889

## EXECUTIVE SUMMARY

Minerals Associates has completed preliminary testwork on three samples from DRD Services Inc. All three samples were reported to have been taken from the same nickel / copper / cobalt project near St. Stephen, NB, Canada. The samples may be described as follows:

Sample 1. Appears to be crushed assay samples comprising minus one inch pieces of a massive sulphide ore assaying 1.29% Cu, 0.86% Ni and 0.08% Co. This sample is up to 90% pyrrhotite with little non-sulphide gangue. Valuable minerals present in the ore were chalcopyrite and pentlandite. No cobalt minerals were identified during this testwork.

Sample 2. Appears to be crushed assay samples comprising minus one inch pieces of a disseminated ore assaying 0.68% Cu, 0.51% Ni and 0.05% Co. This sample is up to 60% pyrrhotite in non-sulphide gangue.

Sample 3. Fist sized pieces of broken massive ore similar to sample 1 but assaying 0.35% Cu and 1.29% Ni.

The following results were achieved in the preliminary testwork:

- All three samples are amenable to flotation beneficiation. Initial results are excellent. About 96% of the Cu, 87% of the Ni and 88% of the Co were recovered into a rougher concentrate from the massive ore. Copper and nickel recoveries were identical to the massive ore for the lower grade disseminated ore. Cobalt recovery decreased to 78%.
- Nickel and cobalt behaved differently from copper in cleaning. Acceptable copper recovery was maintained in cleaning but nickel and cobalt fell out, indicating a liberation problem. Further optimization testwork is required.
- Cu/Ni/Co recovery is effected by the collector system used in flotation. Xanthate collectors achieved lower recoveries than a dithiophosphate/ester collector mixture.

The following conclusions and recommendations have been made:

- Sufficient metallurgy has been developed to setup and operate a small pilot plant for the production of a sample of bulk concentrate to start bacterial leaching and hydrometallurgical testwork.
- More detailed laboratory work and mineralogy is required to optimize the flowsheet and close the circuit before proceeding to plant design and feasibility. This testwork can be undertaken independently, on the laboratory scale, or by expanding the pilot plant program.

## 1.0 INTRODUCTION

On February 28, 1997 Dr. David Desjardins of DRD Services requested a proposal for some preliminary testwork on samples of two ore types from a Nickel / Copper Project located near St. Stephen, NB, Canada. The objectives of the testwork were to: a) determine if the ore is amenable to flotation beneficiation, b) to provide information for design of a detailed development program for the generation of engineering design criteria and prefeasibility, and c) to generate sufficient procedural information to allow the setup and operation of a small pilot plant for generating bulk concentrate for bacterial leaching and hydrometallurgical testwork.

This report describes the results obtained in the preliminary testwork program. Progress was discussed regularly with Dr. Desjardins as the results became available.

MINERALS ASSOCIATES

Robert Salter, Ph. D., P. Eng.
Project Manager

Consulting Metallurgist: Srdjan Bulatovic
Experimental Work: D. Lang, T. Jessup, S. Bulatovic - Lakefield Research Limited

## 2.0 RESULTS AND DISCUSSIONS

### 2.1 Samples Tested

This report refers to three samples as received.

30 kg of crushed massive ore and 20 kg of crushed disseminated ore were received from DRD Services on March 14, 1997. These were designated as Samples 1 and 2 respectively. Head samples assayed:

**Table 1 - Head Assays - Samples 1 and 2.**

| Element | Assays | |
|---|---|---|
| | Massive Sulphide Ore | Disseminated Ore |
| Copper, Cu % | 1.29 | 0.68 |
| Nickel, Ni % | 0.86 | 0.51 |
| Cobalt, Co % | 0.08 | 0.05 |
| Iron, Fe % | 40.20 | 25.7 |
| Sulphur, S % | 21.20 | 12.8 |

A third sample, 10 kg of fist sized lumps of broken massive ore, was received from Cobrun Mining. This sample was used for some initial testwork and assayed at 0.35% Cu and 1.3% Ni.

### 2.2 Test Program

The test program was designed to a) examine the processing characteristics of the two ore types, and b) to determine if either or both ore type is amenable to beneficiation by froth flotation. The bulk Cu/Ni/Co flotation method was exclusively employed in consultation with DRD Services. Neither bacterial nor hydrometallurgical processing will require separation of Cu from Ni/Co.

The reagent scheme evaluated included the Na2CO3-SHQ system using different collectors and fineness of primary grind. SHQ is a pyrrhotite depressant and consists of sodium silicate, hexametaphosphate (Calgon Glass) and Quebracho in a ratio of 40:40:20. Collectors tested included: potassium amyl xanthate (PAX), a mixture of PAX and Senmin PM230 and the mixture of a dithiophosphate (R3477) and ester (AU35).

## 2.3 Initial Laboratory Testwork on Sample 3 - Broken Massive Ore

The ore sample received as nominal 200 mm lumps was used for the initial testwork. Soda ash-SHQ-collector R3477/AU35 reagent scheme was used in these tests. The only variable examined was time in primary grinding. The conditions and results for these tests are given in Table 2. The Cu/Ni rougher recoveries obtained in Test 2 were 92.3% Cu and 84.3% Ni. At a coarser grind both copper and nickel recoveries deteriorated while at a finer grind only nickel recovery was reduced.

**Table 2 - Laboratory Tests on Sample 3 - Lump Massive Ore**

| Test No. | Grind Time min | Product | Weight % | Assays % | | % Distribution | |
|---|---|---|---|---|---|---|---|
| | | | | Cu | Ni | Cu | Ni |
| 1 | 15 | Cu/Ni 2nd Cl Conc | 15.63 | 1.90 | 5.02 | 82.0 | 61.0 |
| | | Cu/Ni Ro Conc | 27.00 | 1.16 | 3.36 | 86.7 | 70.5 |
| | | Cu/Ni Ro Tail | 73.00 | 0.07 | 0.52 | 13.3 | 29.5 |
| | | Head (Calc) | 100.00 | 0.36 | 1.29 | 100.0 | 100.0 |
| 2 | 25 | Cu/Ni 2nd Cl Conc | 18.78 | 1.62 | 4.71 | 86.7 | 70.0 |
| | | Cu/Ni Ro Conc | 46.76 | 0.69 | 2.32 | 92.3 | 84.3 |
| | | Cu/Ni Ro Tail | 53.24 | 0.05 | 0.38 | 7.7 | 15.7 |
| | | Head (Calc) | 100.00 | 0.35 | 1.29 | 100.0 | 100.0 |
| 3 | 35 | Cu/Ni 2nd Cl Conc | 10.97 | 2.65 | 6.00 | 87.0 | 52.1 |
| | | Cu/Ni Ro Conc | 40.27 | 0.77 | 2.45 | 92.3 | 79.3 |
| | | Cu/Ni Ro Tail | 59.73 | 0.04 | 0.43 | 7.7 | 20.7 |
| | | Head (Calc) | 100.00 | 0.33 | 1.24 | 100.0 | 100.0 |

## 2.4 Laboratory Testwork on Sample 1 - Crushed Massive Ore

The testwork on this sample was conducted to evaluate the processing characteristics of the ore as a function again of varying fineness of primary grind and collector types. The conditions and results are presented in Table 3.

Table 3 - Test Conditions and Results for Sample 1 - Crushed Massive Ore

| Test No. | Grind Time min/2000g | Collector Used g/t | Product | Weight % | Assays % |  |  | % Distribution |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | Cu | Ni | Co | Cu | Ni | Co |
| 1 | 70 | PAX PM230 = 100 | Cu/Ni 3rd Cl Conc | 10.65 | 8.52 | 3.19 | 0.35 | 70.3 | 38.7 | 48.5 |
|  |  |  | Cu/Ni 1st Cl Conc | 34.02 | 3.20 | 1.68 | 0.20 | 84.4 | 65.0 | 70.0 |
|  |  |  | Cu/Ni Ro Conc | 50.66 | 2.12 | 1.38 | 0.10 | 87.0 | 79.8 | 80.7 |
|  |  |  | Cu/Ni Ro Tail | 49.34 | 0.34 | 0.36 | 0.03 | 13.0 | 20.2 | 19.3 |
|  |  |  | Head (Calc) | 100.00 | 1.29 | 0.88 | 0.08 | 100.0 | 100.0 | 100.0 |
| 2 | 70 | R3477 AU35 = 80 | Cu/Ni 3rd Cl Conc | 16.60 | 7.00 | 2.95 | 0.33 | 86.8 | 55.2 | 69.2 |
|  |  |  | Cu/Ni 1st Cl Conc | 35.13 | 3.39 | 1.79 | 0.20 | 90.2 | 70.90 | 78.3 |
|  |  |  | Cu/Ni Ro Conc | 57.91 | 2.11 | 1.31 | 0.11 | 92.7 | 85.3 | 84.0 |
|  |  |  | Cu/Ni Ro Tail | 42.09 | 0.23 | 0.31 | 0.03 | 7.3 | 14.7 | 16.0 |
|  |  |  | Head (Calc) | 100.00 | 1.32 | 0.89 | 0.08 | 100.0 | 100.0 | 100.0 |
| 3 | 120 | R3477 AU35 = 80 | Cu/Ni 3rd Cl Conc | 11.37 | 9.89 | 3.47 | 0.38 | 87.4 | 44.7 | 54.0 |
|  |  |  | Cu/Ni 1st Cl Conc | 32.14 | 3.76 | 1.97 | 0.20 | 94.1 | 71.5 | 77.6 |
|  |  |  | Cu/Ni Ro Conc | 53.77 | 2.31 | 1.44 | 0.11 | 96.4 | 87.4 | 88.5 |
|  |  |  | Cu/Ni Ro Tail | 46.23 | 0.10 | 0.24 | 0.02 | 3.6 | 12.6 | 11.5 |
|  |  |  | Head (Calc) | 100.00 | 1.29 | 0.88 | 0.08 | 100.0 | 100.0 | 100.0 |

These results allow the following conclusions:

- Copper, cobalt and nickel recoveries increased with fineness of grind.
- Higher recoveries were achieved with the dithiophosphate/ester collector mixture.
- Since cobalt appears to follow nickel in this testwork, it is likely the mineral association is with the nickel rather than the copper.

## 2.5 Laboratory Testwork on Sample 2 - Disseminated Ore

The disseminated ore sample contains less pyrrhotite than the samples of massive ore. The same test conditions were employed for this ore sample as for the massive ore. Conditions and results are shown in Table 4.

## Table 4 - Conditions and Results for Sample 2 - Disseminated Ore

| Test No. | Grind Time min/2000g | Collector Used g/t | Product | Weight % | Assays % | | | % Distribution | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Cu | Ni | Co | Cu | Ni | Co |
| 4 | 70 | R3477 | Cu/Ni 3rd Cl Conc | 3.87 | 14.50 | 4.55 | 0.58 | 86.6 | 32.8 | 41.6 |
| | | AU35 | Cu/Ni 1st Cl Conc | 16.36 | 3.70 | 1.96 | 0.20 | 93.5 | 59.6 | 64.7 |
| | $K_{80}$ = | = 90 | Cu/Ni Ro Conc | 39.66 | 1.56 | 1.17 | 0.10 | 95.7 | 86.5 | 77.7 |
| | 59 µm | | Cu/Ni Ro Tail | 60.34 | 0.05 | 0.12 | <0.02 | 4.3 | 13.5 | 22.3 |
| | | | Head (Calc) | 100.00 | 0.65 | 0.54 | 0.05 | 100.0 | 100.0 | 100.0 |
| 5 | 90 | R3477 | Cu/Ni 3rd Cl Conc | 5.70 | 10.30 | 3.90 | 0.48 | 89.4 | 40.4 | 52.6 |
| | | AU35 | Cu/Ni 1st Cl Conc | 17.70 | 3.51 | 1.91 | 0.20 | 94.1 | 61.2 | 68.5 |
| | | = 90 | Cu/Ni Ro Conc | 41.68 | 1.52 | 1.15 | 0.10 | 96.0 | 86.3 | 77.8 |
| | | | Cu/Ni Ro Tail | 58.32 | 0.05 | 0.13 | <0.02 | 4.0 | 13.7 | 23.3 |
| | | | Head (Calc) | 100.00 | 0.66 | 0.55 | 0.05 | 100.0 | 100.0 | 100.0 |
| 6 | 70 | PAX | Cu/Ni 3rd Cl Conc | 3.81 | 14.10 | 5.05 | 0.63 | 84.4 | 36.4 | 46.1 |
| | | = 90 | Cu/Ni 1st Cl Conc | 10.20 | 5.53 | 2.78 | 0.3 | 88.5 | 53.7 | 62.0 |
| | $K_{80}$ = | | Cu/Ni Ro Conc | 28.23 | 2.03 | 1.41 | 0.1 | 90.0 | 75.5 | 72.4 |
| | 59 µm | | Cu/Ni Ro Tail | 71.77 | 0.09 | 0.18 | <0.02 | 10.0 | 24.5 | 27.6 |
| | | | Head (Calc) | 100.00 | 0.64 | 0.53 | 0.05 | 100.0 | 100.0 | 100.0 |

The following conclusions have been made.

- The response to flotation was similar for the sample of disseminated ore as to that experienced with the massive ore. Copper, nickel and cobalt recoveries were very similar.
- For both ore types, nickel and cobalt recoveries fell more quickly during cleaning than copper. This suggests a liberation problem between pentlandite and pyrrhotite, since pyrrhotite is being depressed. Subsequent testwork should include provision for a simple regrind of rougher or first cleaner concentrate. The finer grind may require high intensity conditioning (HIC) to increase selectivity and decrease losses to slimes.

## 3.0 CONCLUSIONS and RECOMMENDATIONS

Testwork conducted on the two ore samples of Cu/Ni/Co ore have indicated that the ore is amenable to beneficiation using froth flotation. Satisfactory results were obtained in this preliminary work.

Optimization of metallurgy should be achievable with minimal additional testwork. Since the largest improvements in metallurgy seem directed to regrinding rougher and/or first cleaner concentrate, this testwork can best be undertaken in the pilot plant.

Cobalt follows nickel in recovery.

The project is ready for advancement to a continuous, pilot plant scale.

# APPENDIX

## DETAILS of TESTS

## Test No. 1

**Purpose:** To examine the response of the massive sulphide ore to the following flotation conditions as a preliminary test.

**Procedure:** As shown below.

**Feed:** 2000 grams of minus 10 mesh Composite No. 1 massive ore.

**Grind:** 70 minutes at 65% solids in a laboratory rod mill.

**Conditions:**

| Stage | Reagents Added, grams per tonne | | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | PAX PM230 | Dana 545 Pine Oil | Grind | Cond. | Froth | |
| Grind | 3000 | 300 | 20 | - | 70 | - | - | 7.9 |
| Cu/Ni Rougher 1 | - | - | 50 | 10 | - | 1 | 4 | - |
| 2 | - | - | 30 | 10 | - | 1 | 3.5 | 7.0 |
| Regrind | 100 | 100 | - | - | 15 | - | - | - |
| HIC | - | - | 20 | 15 | - | 15 | - | - |
| Cu/Ni 1st Cleaner | - | - | - | - | - | - | 8 | 6.8 |
| | - | - | 5 | - | - | 1 | 2 | - |
| Cu/Ni 1st Cl Scav | - | - | 2.5 | - | - | 1 | - | - |
| Cu/Ni 2nd Cleaner | 400 | 75 | - | - | - | 1 | 2 | 9.2 |
| | - | - | - | 4 | - | 1 | 2 | - |
| Cu/Ni 3rd Cleaner | 100 | 25 | - | 4 | - | 1 | 1.5 | 9.0 |
| | - | - | 2.5 | 2 | - | 1 | 0.5 | - |

## Metallurgical Results

| Product | | Weight | | Assays,% | | | % Distribution | | |
|---|---|---|---|---|---|---|---|---|---|
| | | g | % | Cu | Ni | Co | Cu | Ni | Co |
| 1 | Cu Ni Cleaner Conc | 212.5 | 10.65 | 8.52 | 3.19 | 0.35 | 70.3 | 38.7 | 48.5 |
| 2 | Cu Ni 3rd Cl. Tail | 59.8 | 3.00 | 1.83 | 1.27 | 0.11 | 4.3 | 4.3 | 4.3 |
| 3 | Cu Ni 2nd Cl. Tail | 290.7 | 14.57 | 0.73 | 0.97 | 0.1 | 8.2 | 16.1 | 13.3 |
| 4 | Cu Ni 1st Cl. Tail | 115.9 | 5.81 | 0.35 | 0.89 | 0.05 | 1.6 | 5.9 | 3.8 |
| 5 | Cu Ni 1st Cl. Tail | 332.1 | 16.64 | 0.20 | 0.78 | 0.05 | 2.6 | 14.8 | 10.8 |
| 6 | Cu Ni Rougher Tail | 984.6 | 49.34 | 0.34 | 0.36 | 0.03 | 13.0 | 20.2 | 19.3 |
| | Head Calc. | 1995.6 | 100.0 | 1.29 | 0.88 | 0.08 | 100.0 | 100.0 | 100.0 |

### Combined Products

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1-2 | Cu Ni 2nd Cl. Conc. | 13.65 | 7.05 | 2.8 | 0.30 | 74.6 | 43.0 | 52.8 |
| 1-3 | Cu Ni 1st Cl. Conc. | 28.21 | 3.79 | 1.84 | 0.2 | 82.8 | 59.1 | 66.1 |
| 1-4 | Cu Ni 1st Cl. +Cl Scav Conc. | 34.02 | 3.20 | 1.68 | 0.2 | 84.4 | 65.0 | 69.9 |
| 1-5 | Cu Ni Rougher Conc. | 50.66 | 2.21 | 1.38 | 0.1 | 87.0 | 79.8 | 80.7 |

## Test No. 2

Purpose: To repeat the conditions of Test 1, but replace PAX/PM230 mixture with the R3477/AU35 mixture.

Procedure: As shown below.

Feed: 2000 grams of minus 10 mesh Composite No. 1 massive ore.

Grind: 70 minutes at 65% solids in a laboratory rod mill.

Conditions:

| Stage | Reagents Added, grams per tonne | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | R3477/AU35 | Grind | Cond. | Froth | |
| Grind | 3000 | 300 | 20 | 70 | - | - | 7.8 |
| Cu/Ni Rougher 1 | - | - | 20 | - | 1 | 3 | - |
| 2 | - | - | 20 | - | 1 | 4 | - |
| 3 | - | - | 6 | - | 1 | 2 | - |
| Regrind | 3000 | 100 | - | 30 | - | - | - |
| HIC | - | - | 20 | - | 15 | - | - |
| Cu/Ni 1st Cleaner | - | - | - | - | - | 5 | 9.6 |
| Cu/Ni 1st Cl Scav | - | - | 6 | - | 1 | 2 | 9.4 |
| Cu/Ni 2nd Cleaner | X | 75 | 2 | - | 1 | 4 | 9.2 |
| | - | - | 4 | - | 1 | 2 | - |
| Cu/Ni 3rd Cleaner | X | 25 | - | - | 1 | 1 | 9.2 |
| | - | - | 6 | - | 1 | 2.5 | - |
| | - | - | 4 | - | 1 | 1 | - |

## Metallurgical Results

| Product | | Weight | | Assays,% | | | % Distribution | | |
|---|---|---|---|---|---|---|---|---|---|
| | | g | % | Cu | Ni | Co | Cu | Ni | Co |
| 1 | Cu Ni Cleaner Conc | 337.0 | 16.60 | 6.90 | 2.95 | 0.33 | 86.8 | 55.2 | 69.2 |
| 2 | Cu Ni 3rd Cl. Tail | 107.6 | 5.30 | 0.32 | 0.86 | 0.06 | 1.3 | 5.1 | 4.0 |
| 3 | Cu Ni 2nd Cl. Tail | 144.3 | 7.11 | 0.21 | 0.70 | 0.0 | 1.1 | 5.6 | 2.7 |
| 4 | Cu Ni 1st Cl. Tail | 124.4 | 6.13 | 0.21 | 0.73 | 0.03 | 1.0 | 5.0 | 2.3 |
| 5 | Cu Ni 1st Cl. Tail | 462.5 | 22.78 | 0.14 | 0.56 | 0.02 | 2.4 | 14.4 | 5.8 |
| 6 | Cu Ni Rougher Tail | 854.7 | 42.09 | 0.23 | 0.31 | 0.03 | 7.3 | 14.7 | 16.0 |
| | Head Calc. | 2030.5 | 100.0 | 1.32 | 0.89 | 0.08 | 100.0 | 100.0 | 100.0 |

### Combined Products

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1-2 | Cu Ni 2nd Cl. Conc. | 21.90 | 5.31 | 2.4 | 0.26 | 88.1 | 60.3 | 73.3 |
| 1-3 | Cu Ni 1st Cl. Conc. | 29.00 | 4.06 | 2.02 | 0.2 | 89.3 | 65.9 | 76.0 |
| 1-4 | Cu Ni 1st Cl. +Cl Scav Conc. | 35.13 | 3.39 | 1.79 | 0.2 | 90.2 | 70.9 | 78.3 |
| 1-5 | Cu Ni Rougher Conc. | 57.91 | 2.11 | 1.31 | 0.1 | 92.7 | 85.3 | 84.0 |

# Test No. 3

Purpose: To repeat the conditions of Test 2, but extend the primary grind to 120 minutes.

Procedure: As shown below.

Feed: 2000 grams of minus 10 mesh Composite No. 1 massive ore.

Grind: 120 minutes at 65% solids in a laboratory rod mill.

Conditions:

| Stage | Reagents Added, grams per tonne | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | R3477/AU35 | Grind | Cond. | Froth | |
| Grind | 6000 | 300 | 20 | 120 | - | - | 9.1 |
| Cu/Ni Rougher 1 | - | - | 20 | - | 1 | 3 | - |
| 2 | - | - | 20 | - | 1 | 5 | - |
| 3 | - | - | 12 | - | 1 | 4 | 8.7 |
| 4 | - | - | 4 | - | 1 | 1 | - |
| Cu/Ni Regr (RM) | 3000 | 100 | - | 15 | - | - | - |
| HIC | - | - | 20 | - | 15 | - | 9.6 |
| Cu/Ni 1st Cleaner | - | - | - | - | - | 5 | 9.6 |
| Cu/Ni 1st Cl Scav | - | - | 4 | - | 1 | 2 | - |
| Cu/Ni 2nd Cleaner | - | 75 | - | - | 1 | 2 | 9.3 |
| | - | - | 4 | - | 1 | 1 | - |
| Cu/Ni 3rd Cleaner | X | 25 | - | - | 1 | 2 | 9.3 |
| | - | - | 4 | - | 1 | - | - |

## Metallurgical Results

| Product | | Weight | | Assays,% | | | % Distribution | | |
|---|---|---|---|---|---|---|---|---|---|
| | | g | % | Cu | Ni | Co | Cu | Ni | Co |
| 1 | Cu Ni Cleaner Conc | 227.7 | 11.37 | 9.89 | 3.47 | 0.38 | 87.4 | 44.7 | 54.0 |
| 2 | Cu Ni 3rd Cl. Tail | 107.7 | 5.38 | 0.54 | 1.40 | 0.13 | 2.3 | 8.5 | 8.7 |
| 3 | Cu Ni 2nd Cl. Tail | 190.0 | 9.49 | 0.33 | 1.01 | 0.1 | 2.4 | 10.8 | 8.3 |
| 4 | Cu Ni 1st Cl. Tail | 118.2 | 5.90 | 0.42 | 1.12 | 0.09 | 1.9 | 7.5 | 6.6 |
| 5 | Cu Ni 1st Cl. Tail | 433.1 | 21.63 | 0.14 | 0.65 | 0.04 | 2.4 | 15.9 | 10.8 |
| 6 | Cu Ni Rougher Tail | 925.6 | 46.23 | 0.10 | 0.24 | 0.02 | 3.6 | 12.6 | 11.5 |
| | Head Calc. | 2002.3 | 100.0 | 1.29 | 0.88 | 0.08 | 100.0 | 100.0 | 100.0 |

### Combined Products

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1-2 | Cu Ni 2nd Cl. Conc. | | 16.75 | 6.89 | 2.8 | 0.30 | 89.7 | 53.2 | 62.7 |
| 1-3 | Cu Ni 1st Cl. Conc. | | 26.24 | 4.52 | 2.16 | 0.2 | 92.1 | 64.0 | 71.0 |
| 1-4 | Cu Ni 1st Cl. +Cl Scav Conc. | | 32.14 | 3.76 | 1.97 | 0.2 | 94.1 | 71.5 | 77.6 |
| 1-5 | Cu Ni Rougher Conc. | | 53.77 | 2.31 | 1.44 | 0.1 | 96.4 | 87.4 | 88.5 |

## Test No. 4

Purpose: To study the flotation response of the disseminated ore using the conditions outlined below.

Procedure: As shown below.

Feed: 2000 grams of minus 10 mesh Composite No. 2 disseminated ore.

Grind: 70 minutes at 65% solids in a laboratory rod mill.

Conditions:

| Stage | Reagents Added, grams per tonne | | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | CMC7LT | R3477<br>AU35 | Grind | Cond. | Froth | |
| Grind | 3000 | 300 | - | 20 | 70 | - | - | 8.6 |
| Cu/Ni Rougher 1 | 250 | - | - | 20 | - | 1 | 4 | 9.0 |
| 2 | - | - | - | 20 | - | 1 | 5 | - |
| 3 | - | - | - | 6 | - | 1 | 3 | - |
| 4 | - | - | - | 6 | - | 1 | 2 | - |
| Regrind (RM) | 3000 | 100 | - | - | 15 | - | - | - |
| HIC | - | - | - | 20 | - | 15 | - | 9.9 |
| Cu/Ni 1st Cleaner | - | - | - | - | - | - | 5 | - |
| Cu/Ni 1st Cl Scav | - | - | - | 6 | - | 1 | 2 | - |
| Cu/Ni 2nd Cleaner | X | 75 | - | - | - | 1 | 4 | 9.5 |
| | - | - | - | 4 | - | 1 | 2 | - |
| Cu/Ni 3rd Cleaner | X | 25 | - | - | - | 1 | 2 | 9.5 |
| | - | - | - | 4 | - | 1 | 1 | - |

## Metallurgical Results

| Product | | Weight | | Assays,% | | | % Distribution | | |
|---|---|---|---|---|---|---|---|---|---|
| | | g | % | Cu | Ni | Co | Cu | Ni | Co |
| 1 | Cu Ni Cleaner Conc | 77.6 | 3.87 | 14.50 | 4.55 | 0.58 | 86.6 | 32.8 | 41.6 |
| 2 | Cu Ni 3rd Cl. Tail | 72.8 | 3.63 | 0.68 | 1.88 | 0.21 | 3.8 | 12.7 | 14.1 |
| 3 | Cu Ni 2nd Cl. Tail | 94.2 | 4.70 | 0.26 | 0.91 | 0.1 | 1.9 | 8.0 | 5.2 |
| 4 | Cu Ni 1st Cl. Tail | 83.4 | 4.16 | 0.19 | 0.79 | 0.05 | 1.2 | 6.1 | 3.8 |
| 5 | Cu Ni 1st Cl. Tail | 467.0 | 23.30 | 0.06 | 0.62 | 0.03 | 2.2 | 26.9 | 12.9 |
| 6 | Cu Ni Rougher Tail | 1209.5 | 60.34 | 0.05 | 0.12 | <0.02 | 4.3 | 13.5 | 22.3 |
| | Head Calc. | 2004.5 | 100.0 | 0.65 | 0.54 | 0.05 | 100.0 | 100.0 | 100.0 |

### Combined Products

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1-2 | Cu Ni 2nd Cl. Conc. | 7.50 | 7.81 | 3.3 | 0.40 | 90.4 | 45.5 | 55.7 |
| 1-3 | Cu Ni 1st Cl. Conc. | 12.20 | 4.90 | 2.35 | 0.3 | 92.3 | 53.5 | 60.9 |
| 1-4 | Cu Ni 1st Cl. +Cl Scav Conc. | 16.36 | 3.70 | 1.96 | 0.2 | 93.5 | 59.6 | 64.7 |
| 1-5 | Cu Ni Rougher Conc. | 39.66 | 1.56 | 1.17 | 0.1 | 95.7 | 85.5 | 77.7 |

## Test No. 5

Purpose: To repeat the conditions of Test 4, but increase the primary grind fro 70 to 90 minutes.

Procedure: As shown below.

Feed: 2000 grams of minus 10 mesh Composite No. 2 disseminated ore.

Grind: 90 minutes at 65% solids in a laboratory rod mill.

Conditions:

| Stage | Reagents Added, grams per tonne | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | R3477/AU35 | Grind | Cond. | Froth | |
| Grind | 3000 | 300 | 20 | 90 | - | - | 8.6 |
| Cu/Ni Rougher 1 | X | - | 20 | - | 1 | 4 | 9.0 |
| 2 | - | - | 20 | - | 1 | 5 | - |
| 3 | - | - | 6 | - | 1 | 3 | - |
| 4 | - | - | 6 | - | 1 | 2 | - |
| Regrind (RM) | 3000 | 100 | - | 15 | - | - | - |
| HIC | - | - | 20 | - | 15 | - | 9.9 |
| Cu/Ni 1st Cleaner | - | - | - | - | - | 5 | - |
| Cu/Ni 1st Cl Scav | - | - | 6 | - | 1 | 2 | - |
| Cu/Ni 2nd Cleaner | X | 75 | - | - | 1 | 3 | 9.5 |
| | - | - | 4 | - | 1 | 2 | - |
| Cu/Ni 3rd Cleaner | X | 25 | - | - | 1 | 2 | 9.5 |
| | - | - | 4 | - | 1 | 1 | - |

## Metallurgical Results

| Product | | Weight | | Assays,% | | | % Distribution | | |
|---|---|---|---|---|---|---|---|---|---|
| | | g | % | Cu | Ni | Co | Cu | Ni | Co |
| 1 | Cu Ni Cleaner Conc | 110.8 | 5.73 | 10.30 | 3.90 | 0.48 | 89.4 | 40.4 | 52.6 |
| 2 | Cu Ni 3rd Cl. Tail | 56.1 | 2.90 | 0.54 | 1.39 | 0.13 | 2.4 | 7.3 | 7.2 |
| 3 | Cu Ni 2nd Cl. Tail | 103.8 | 5.37 | 0.19 | 0.83 | 0.1 | 1.5 | 8.0 | 5.1 |
| 4 | Cu Ni 1st Cl. Tail | 71.6 | 3.70 | 0.14 | 0.82 | 0.05 | 0.8 | 5.5 | 3.5 |
| 5 | Cu Ni 1st Cl. Tail | 463.8 | 23.98 | 0.05 | 0.58 | 0.02 | 1.9 | 25.1 | 9.2 |
| 6 | Cu Ni Rougher Tail | 1128.0 | 58.32 | 0.05 | 0.13 | <0.02 | 4.0 | 13.7 | 22.3 |
| | Head Calc. | 1934.1 | 100.0 | 0.66 | 0.55 | 0.05 | 100.0 | 100.0 | 100.0 |

**Combined Products**

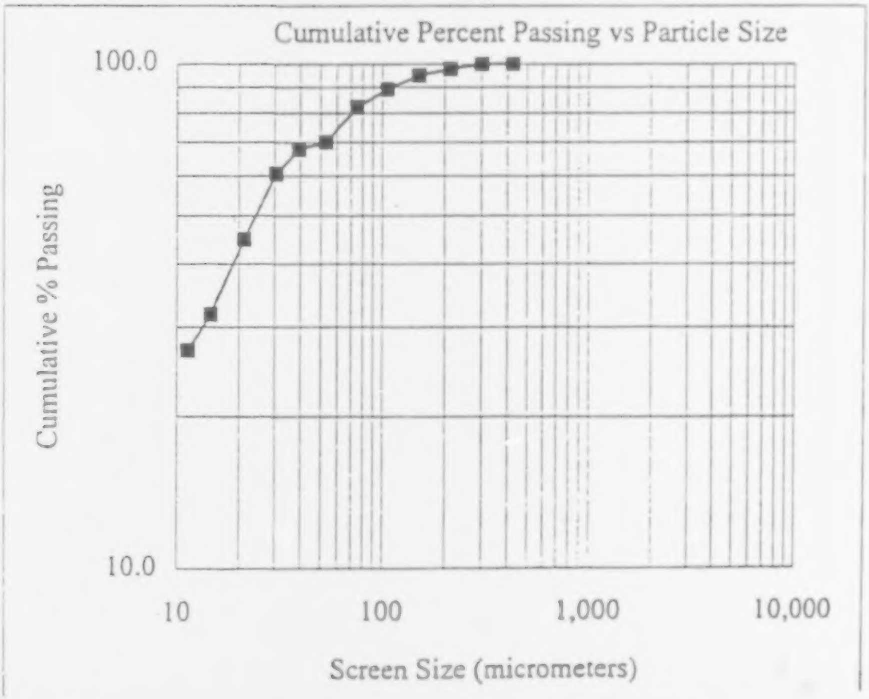
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1-2 | Cu Ni 2nd Cl. Conc. | 8.63 | 7.02 | 3.1 | 0.36 | 91.8 | 47.6 | 59.8 |
| 1-3 | Cu Ni 1st Cl. Conc. | 14.00 | 4.40 | 2.20 | 0.2 | 93.3 | 55.7 | 65.0 |
| 1-4 | Cu Ni 1st Cl. +Cl Scav Conc. | 17.70 | 3.51 | 1.91 | 0.2 | 94.1 | 61.2 | 68.5 |
| 1-5 | Cu Ni Rougher Conc. | 41.68 | 1.52 | 1.15 | 0.1 | 96.0 | 86.3 | 77.7 |

Company **Lakefield Research** LR-5084

## Size Distribution Analysis

**Sample:** Flot N Feed **Test No.:** 5

| Dry Solids S.G.= | | 3.36 | Water Temperature = | | 4.00 C° |
|---|---|---|---|---|---|
| Size | | Weight | % Retained | | % Passing |
| Mesh | µm | grams | Individual | Cumulative | Cumulative |
| 35 | 425 | 0.00 | 0.0 | 0.0 | 100.0 |
| 48 | 300 | 0.00 | 0.0 | 0.0 | 100.0 |
| 65 | 212 | 1.46 | 2.2 | 2.2 | 97.8 |
| 100 | 150 | 1.89 | 2.8 | 5.0 | 95.0 |
| 150 | 106 | 3.90 | 5.9 | 10.9 | 89.1 |
| 200 | 75 | 4.68 | 7.0 | 17.9 | 82.1 |
| 270 | 53 | 8.06 | 12.1 | 30.0 | 70.0 |
| | 39 | 1.52 | 2.3 | 32.3 | 67.7 |
| | 30 | 4.77 | 7.2 | 39.4 | 60.6 |
| | 21 | 10.49 | 15.7 | 55.2 | 44.8 |
| | 15 | 8.69 | 13.0 | 68.2 | 31.8 |
| | 11 | 3.18 | 4.8 | 73.0 | 27.0 |
| Pan | -11 | 17.99 | 27.0 | 100.0 | 0.0 |
| **Total** | - | **66.63** | **100.0** | - | - |
| K80 | 71 | | | | |



## Test No. 6

Purpose: To repeat the general conditions of Test 4, but replace R3477/AU35 with PAX.

Procedure: As shown below.

Feed: 2000 grams of minus 10 mesh Composite No. 2 disseminated ore.

Grind: 70 minutes at 65% solids in a laboratory rod mill.

Conditions:

| Stage | Reagents Added, grams per tonne | | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | PAX | MIBC | Grind | Cond. | Froth | |
| Grind | 3000 | 300 | - | 20 | 70 | - | - | - |
| Cu/Ni Rougher 1 | X | - | 20 | 10 | - | 1 | 3 | 9.0 |
| 2 | - | - | 20 | 8 | - | 1 | 5 | - |
| 3 | - | - | 6 | 4 | - | 1 | 3 | - |
| 4 | - | - | 6 | 4 | - | 1 | 2 | - |
| Regrind (RM) | 3000 | 100 | - | - | 15 | - | - | - |
| HIC | - | - | 20 | 6 | - | 15 | - | 9.9 |
| Cu/Ni 1st Cleaner | - | - | - | - | - | - | 5 | - |
| Cu/Ni 1st Cl Scav | - | - | 6 | - | - | 1 | 2 | - |
| Cu/Ni 2nd Cleaner | X | 75 | - | - | - | 1 | 3 | 9.5 |
| | - | - | - | 4 | - | 1 | 2 | - |
| Cu/Ni 3rd Cleaner | X | 25 | - | - | - | 1 | 2 | 9.5 |
| | - | - | - | 4 | - | 1 | 2 | - |

## Metallurgical Results

| Product | | Weight | | Assays,% | | | % Distribution | | |
|---|---|---|---|---|---|---|---|---|---|
| | | g | % | Cu | Ni | Co | Cu | Ni | Co |
| 1 | Cu Ni Cleaner Conc | 73.0 | 3.81 | 14.10 | 5.05 | 0.63 | 84.4 | 36.4 | 46.1 |
| 2 | Cu Ni 3rd Cl. Tail | 37.3 | 1.95 | 0.89 | 2.31 | 0.26 | 2.7 | 8.5 | 9.7 |
| 3 | Cu Ni 2nd Cl. Tail | 34.6 | 1.81 | 0.26 | 0.91 | 0.1 | 0.7 | 3.1 | 2.1 |
| 4 | Cu Ni 1st Cl. Tail | 50.5 | 2.64 | 0.17 | 1.12 | 0.08 | 0.7 | 5.6 | 4.1 |
| 5 | Cu Ni 1st Cl. Tail | 345.7 | 18.04 | 0.05 | 0.64 | 0.03 | 1.4 | 21.9 | 10.4 |
| 6 | Cu Ni Rougher Tail | 1375.4 | 71.77 | 0.09 | 0.18 | <0.02 | 10.0 | 24.5 | 27.6 |
| | Head Calc. | 1916.5 | 100.0 | 0.64 | 0.53 | 0.05 | 100.0 | 100.0 | 100.0 |

### Combined Products

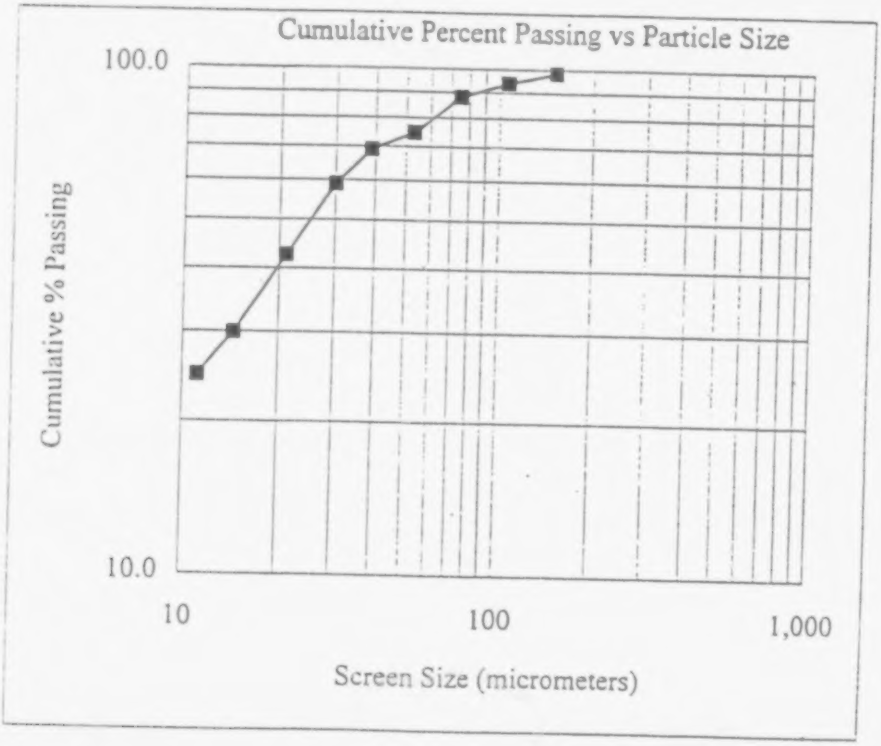
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1-2 | Cu Ni 2nd Cl. Conc. | 5.76 | 9.63 | 4.1 | 0.50 | 87.1 | 45.0 | 55.9 |
| 1-3 | Cu Ni 1st Cl. Conc. | 7.56 | 7.39 | 3.36 | 0.4 | 87.8 | 48.1 | 57.9 |
| 1-4 | Cu Ni 1st Cl. +Cl Scav Conc. | 10.20 | 5.53 | 2.78 | 0.3 | 88.5 | 53.7 | 62.0 |
| 1-5 | Cu Ni Rougher Conc. | 28.23 | 2.03 | 1.41 | 0.1 | 90.0 | 75.5 | 72.4 |

Company Lakefield Research LR-5084

## Size Distribution Analysis

**Sample:** Flot N Feed **Test No.:** 6

| Dry Solids S.G.= | | 3.41 | Water Temperature = | | 4.00 C° |
|---|---|---|---|---|---|
| Size | | Weight | % Retained | | % Passing |
| Mesh | µm | grams | Individual | Cumulative | Cumulative |
| 100 | 150 | 0.94 | 1.8 | 1.8 | 98.2 |
| 150 | 106 | 2.37 | 4.5 | 6.2 | 93.8 |
| 200 | 75 | 3.00 | 5.6 | 11.9 | 88.1 |
| 270 | 53 | 7.16 | 13.5 | 25.4 | 74.6 |
| | 39 | 2.93 | 5.5 | 30.9 | 69.1 |
| | 30 | 5.45 | 10.3 | 41.1 | 58.9 |
| | 21 | 8.70 | 16.4 | 57.5 | 42.5 |
| | 14 | 6.68 | 12.6 | 70.1 | 29.9 |
| | 11 | 2.81 | 5.3 | 75.4 | 24.6 |
| | -11 | 13.09 | 24.6 | 100.0 | 0.0 |
| **Total** | - | **53.13** | **100.0** | - | - |
| **K80 =** | **59** | | | | |


Cumulative Percent Passing vs Particle Size

## Test No. RS-1

**Purpose:** A preliminary test on the copper/nickel ore to examine the processing characteristics of the ore.

**Procedure:** As shown below.

**Feed:** 1000 grams of minus 10 mesh ore sample.

**Grind:** 20 minutes at 65% solids in a laboratory rod mill.

**Conditions:**

| Stage | Reagents Added, grams per tonne | | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | R3477<br>AU35 | PAX | Grind | Cond. | Froth | |
| Grind | 2000 | 500 | 15 | - | 20 | - | - | 9.0 |
| Cu/Ni Rougher 1 | - | - | - | 5 | - | 1 | 3 | - |
| 2 | - | - | 4 | 5 | - | 1 | 2 | - |
| 3 | - | - | 4 | 5 | - | 1 | 2 | - |
| Cu/Ni 1st Cleaner | 600 | 200 | - | - | - | 3 | 4 | - |
| | - | - | 2 | 5 | - | 1 | 2 | - |
| Cu/Ni 2nd Cleaner | 300 | 100 | 3 | - | - | 1 | 3 | - |

## Metallurgical Results

| Product | Weight | | Assays,% | | % Distribution | |
|---|---|---|---|---|---|---|
| | g | % | Cu | Ni | Cu | Ni |
| 1 Cu Ni Cleaner Conc | 152.5 | 15.63 | 1.90 | 5.02 | 82.0 | 61.0 |
| 2 Cu Ni 2nd Cl. Tail | 17.5 | 1.79 | 0.15 | 1.08 | 0.7 | 1.5 |
| 3 Cu Ni 1st Cl. Tail | 93.4 | 9.58 | 0.15 | 1.08 | 4.0 | 8.0 |
| 4 Cu Ni Rougher Tail | 712.0 | 73.00 | 0.07 | 0.52 | 13.3 | 29.5 |
| Head Calc. | 975.4 | 100.0 | 0.36 | 1.29 | 100.0 | 100.0 |

### Combined Products

| | | | | | |
|---|---|---|---|---|---|
| 1-2 Cu Ni 1st Cl. Conc. | 17.43 | 1.72 | 4.61 | 82.7 | 62.5 |
| 1-3 Cu Ni Rougher Conc. | 27.00 | 1.16 | 3.36 | 86.7 | 70.5 |

## Test No. RS-2

**Purpose:** A repeat the conditions of Test RS-1 but at a higher collector additions and a finer grind.

**Procedure:** As shown below.

**Feed:** 1000 grams of minus 10 mesh ore sample (unknown origin).

**Grind:** 35 minutes at 65% solids in a laboratory rod mill.

**Conditions:**

| Stage | Reagents Added, grams per tonne | | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | R3477<br>AU35 | PAX | Grind | Cond. | Froth | |
| Grind | 3000 | 500 | 32 | - | 35 | - | - | - |
| Cu/Ni Rougher 1 | - | - | - | - | - | 1 | 3 | - |
| 2 | - | - | 6 | 15 | - | 1 | 3 | - |
| Cu/Ni 1st Cleaner | 200 | 200 | -- | - | - | 3 | 5 | - |
| Cu/Ni 2nd Cleaner | 200 | 100 | - | - | - | 1 | 3 | - |

## Metallurgical Results

| Product | | Weight | | Assays,% | | % Distribution | |
|---|---|---|---|---|---|---|---|
| | | g | % | Cu | Ni | Cu | Ni |
| 1 | Cu Ni Cleaner Conc | 183.0 | 18.78 | 1.62 | 4.71 | 86.7 | 68.7 |
| 2 | Cu Ni 2nd Cl. Tail | 154.3 | 15.84 | 0.07 | 0.77 | 3.3 | 9.5 |
| 3 | Cu Ni 1st Cl. Tail | 118.3 | 12.14 | 0.06 | 0.65 | 2.2 | 6.1 |
| 4 | Cu Ni Rougher Tail | 518.8 | 53.24 | 0.05 | 0.38 | 7.7 | 15.7 |
| | Head Calc. | 974.4 | 100.0 | 0.35 | 1.29 | 100.0 | 100.0 |

### Combined Products

| | | | | | | |
|---|---|---|---|---|---|---|
| 1-2 | Cu Ni 1st Cl. Conc. | 34.62 | 0.91 | 2.91 | 90.1 | 78.2 |
| 1-3 | Cu Ni Rougher Conc. | 46.76 | 0.69 | 2.32 | 92.3 | 84.3 |

## Test No. RS-3

| | |
|---|---|
| Purpose: | To investigate the effect of fine grind and omission of QHS. |
| Procedure: | As shown below. |
| Feed: | 1000 grams of minus 10 mesh Cu/Ni ore. |
| Grind: | 45 minutes at 65% solids in a laboratory rod mill. |

Conditions:

| Stage | Reagents Added, grams per tonne | | | | Time, minutes | | | pH |
|---|---|---|---|---|---|---|---|---|
| | $Na_2CO_3$ | SHQ | R3477<br>AU35 | PAX | Grind | Cond. | Froth | |
| Grind | 3000 | 300 | 32 | - | 45 | - | - | - |
| Cu/Ni Rougher 1 | - | - | - | - | - | 1 | 3 | - |
| 2 | - | - | 4 | 10 | - | 1 | 4 | - |
| Cu/Ni 1st Cleaner | 300 | 100 | 4 | - | - | 1 | 4 | - |
| 2 | - | - | 2 | 2 | - | 1 | 2 | - |
| Cu/Ni 2nd Clenaer | 300 | 100 | 2 | - | - | 3 | 3 | - |
| | - | - | 2 | 2 | - | 1 | 2 | - |
| Cu/Ni 3rd Cleaner | 200 | 50 | 2 | - | - | 2 | 3 | - |
| | - | - | - | - | - | 1 | 1 | - |

## Metallurgical Results

| Product | Weight | | Assays,% | | % Distribution | |
|---|---|---|---|---|---|---|
| | g | % | Cu | Ni | Cu | Ni |
| 1 Cu Ni Cleaner Conc | 44.4 | 4.27 | 6.47 | 7.90 | 82.6 | 27.2 |
| 2 Cu Ni 3rd Cl. Tail | 69.6 | 6.70 | 0.22 | 4.62 | 4.4 | 24.9 |
| 3 Cu Ni 2nd Cl. Tail | 118.5 | 11.41 | 0.07 | 1.82 | 2.4 | 16.7 |
| 4 Cu Ni 1st Cl. Tail | 185.9 | 17.89 | 0.06 | 0.73 | 2.9 | 10.5 |
| 5 Cu Ni Rougher Tail | 620.5 | 59.73 | 0.04 | 0.43 | 7.7 | 20.7 |
| Head Calc. | 1038.9 | 100.0 | 0.33 | 1.24 | 100.0 | 100.0 |

### Combined Products

| | | | | | |
|---|---|---|---|---|---|
| 1-2 Cu Ni 2nd Cl. Conc. | 10.97 | 2.65 | 5.9 | 87.0 | 52.1 |
| 1-3 Cu Ni 1st Cl. Conc. | 22.38 | 1.34 | 3.82 | 89.4 | 68.8 |
| 1-4 Cu Ni Rougher Conc. | 40.27 | 0.77 | 2.45 | 92.3 | 79.3 |

# Appendix B

## TUNS Flotation Trials

FLOTATION TEST-3 (New Ore) December 9, 1997

PURPOSE: TO PRODUCE A CLEANER CONCENTRATE FROM NICKLE ORE USING TWO STAGES OF ROUGHER FLOTATION

FEED: A 1000 gram sample of ore crushed to minus 4.0 mm by two stages of crushing, jaw and cone.

PROCEDURE: A two stage rougher flotation was carried out, followed by three stages of cleaning on the rougher concentrate. Flotation was carried out in a Denver D12 lab flotation machine. Flotation speeds were 1200 RPM. Flotation was carried out at 35% solids after grinding at 66.6% solids for 45 min. in rod mill with seven rods. The ore was grounded with 3 kg/t sodium carbonate and 0.3 kg/t SHQ (40% sodium silicate, 40% sodium hexa-metaphosphate and 20% quebracho). All products were filtered, dried, weighed and assayed for nickle, cobalt and copper.

REAGENTS: PAX (4 g/L sol) and Senmin PM230 (4g/L).

| STAGE | TIME (MIN) | REAGENTS ADDED (kg/t) PAX | REAGENTS ADDED (kg/t) PM230 | pH |
|---|---|---|---|---|
| CONDITION | 1 | 0.10 | 0.10 | 8.9 |
| PRIMARY FLOAT | 3 | | | |
| CONDITION | 1 | 0.08 | 0.08 | |
| SECONDARY FLOAT | 4 | | | |
| CONDITION | 1/4 | 0.04 | 0.04 | |
| 1st CLEANER | 3 | | | |
| 2nd CLEANER | 2 | | | |
| 3rd CLEANER | 2 1/2 | | | |

| | | % | | | % Distribution | | |
|---|---|---|---|---|---|---|---|
| PRODUCT | % WEIGHT | Ni | Co | Cu | Ni | Co | Cu |
| CLEANER CONC | 12.63 | 7.40 | 0.677 | 4.80 | 61.20 | 77.50 | 85.41 |
| 3rd CLEANER TAIL | 5.8 | 1.60 | 0.084 | 0.348 | 6.08 | 4.42 | 2.84 |
| 2nd CLEANER TAIL | 12.89 | 0.99 | 0.051 | 0.178 | 8.36 | 5.96 | 3.23 |
| 1st CLEANER TAIL | 16.82 | 0.67 | 0.024 | 0.082 | 7.38 | 3.66 | 1.94 |
| ROUGHER TAIL | 51.86 | 0.50 | 0.018 | 0.090 | 16.98 | 8.46 | 6.58 |
| CALCULATED HEAD | 100.00 | 1.53 | 0.110 | 0.710 | 100.00 | 100.00 | 100.00 |

Grind:

| Size (mm) | % WEIGHT |
|---|---|
| +0.25 | |
| -0.25+0.15 | |
| -0.15+0.075 | |
| -0.075+0.045 | |
| -0.045 | |

FLOTATION TEST-2 (New Ore) November 27, 1997

PURPOSE: TO PRODUCE A CLEANER CONCENTRATE FROM NICKLE ORE USING TWO STAGES OF ROUGHER FLOTATION

FEED: A 1000 gram sample of ore crushed to minus 4.0 mm by two stages of crushing, jaw and cone.

PROCEDURE: A two stage rougher flotation was carried out, followed by three stages of cleaning on the rougher concentrate. Flotation was carried out in a Denver D12 lab flotation machine. Flotation speeds were 1200 RPM. Flotation was carried out at 35% solids after grinding at 66.6% solids for 45 min. in rod mill with seven rods. The ore was grounded with 3 kg/t sodium carbonate and 0.3 kg/t SHQ (40% sodium silicate, 40% sodium hexa-metaphosphate and 20% quebracho). All products were filtered, dried, weighed and assayed for nickle, cobalt and copper.

REAGENTS: PAX (4 g/L sol) and Senmin PM230 (4g/L).

| STAGE | TIME (MIN) | REAGENTS ADDED (kg/t) PAX | PM230 |
|---|---|---|---|
| CONDITION | 1 | 0.08 | 0.08 |
| PRIMARY FLOAT | 2 | | |
| CONDITION | 1 | 0.08 | 0.08 |
| SECONDARY FLOAT | 6 | | |
| CONDITION | 1/4 | 0.02 | 0.02 |
| 1st CLEANER | 4 | | |
| 2nd CLEANER | 3 | | |
| 3rd CLEANER | 3 | | |

| | | % | | | % Distribution | | |
|---|---|---|---|---|---|---|---|
| PRODUCT | % WEIGHT | Ni | Co | Cu | Ni | Co | Cu |
| CLEANER CONC | 3.83 | 13.40 | 1.230 | 10.63 | 33.33 | 42.56 | 59.61 |
| 3rd CLEANER TAIL | 3.32 | 6.50 | 0.572 | 2.80 | 14.02 | 16.74 | 13.62 |
| 2nd CLEANER TAIL | 8.60 | 3.03 | 0.266 | 1.07 | 16.93 | 20.18 | 13.47 |
| 1st CLEANER TAIL | 18.27 | 1.06 | 0.048 | 0.165 | 12.58 | 7.75 | 4.41 |
| ROUGHER TAIL | 65.98 | 0.54 | 0.022 | 0.092 | 23.14 | 12.77 | 8.89 |
| CALCULATED HEAD | 100.00 | 1.54 | 0.114 | 0.683 | 100.00 | 100.00 | 100.00 |

Grind:

| Size (mm) | % WEIGHT |
|---|---|
| +0.25 | |
| -0.25+0.15 | |
| -0.15+0.075 | |
| -0.075+0.045 | |
| -0.045 | |

FLOTATION TEST-1 (New Ore) November 25, 1997

PURPOSE: TO PRODUCE A CLEANER CONCENTRATE FROM NICKLE ORE USING TWO STAGES OF ROUGHER FLOTATION

FEED: A 1000 gram sample of ore crushed to minus 4.0 mm by two stages of crushing, jaw and cone.

PROCEDURE: A two stage rougher flotation was carried out, followed by three stages of cleaning on the rougher concentrate. Flotation was carried out in a Denver D12 lab flotation machine. Flotation speeds were 1200 RPM. Flotation was carried out at 35% solids after grinding at 66.6% solids for 45 min. in rod mill with seven rods. The ore was grounded with 3 kg/t sodium carbonate and 0.3 kg/t SHQ (40% sodium silicate, 40% sodium hexa-metaphosphate and 20% quebracho). All products were filtered, dried, weighed and assayed for nickle, cobalt and copper.

REAGENTS: PAX (4 g/L sol) and Senmin PM230 (4g/L).

| STAGE | TIME (MIN) | REAGENTS ADDED (kg/t) PAX | PM230 |
|---|---|---|---|
| CONDITION | 1 | 0.08 | 0.08 |
| PRIMARY FLOAT | 2 | | |
| CONDITION | 1 | 0.04 | 0.04 |
| SECONDARY FLOAT | 6 | | |
| CONDITION | 1/4 | 0.02 | 0.02 |
| 1st CLEANER | 4 | | |
| 2nd CLEANER | 3 | | |
| 3rd CLEANER | 3 | | |

| PRODUCT | % WEIGHT | % Ni | Co | Cu | % Distribution Ni | Co | Cu |
|---|---|---|---|---|---|---|---|
| CLEANER CONC | 8.53 | 9.17 | 0.795 | 6.12 | 54.60 | 69.55 | 81.44 |
| 3rd CLEANER TAIL | 4.78 | 2.54 | 0.192 | 0.63 | 8.47 | 9.41 | 4.68 |
| 2nd CLEANER TAIL | 6.91 | 1.27 | 0.062 | 0.22 | 6.13 | 4.39 | 2.36 |
| 1st CLEANER TAIL | 15.67 | 0.73 | 0.030 | 0.096 | 7.98 | 4.82 | 2.33 |
| ROUGHER TAIL | 64.11 | 0.51 | 0.018 | 0.092 | 22.82 | 11.83 | 9.19 |
| CALCULATED HEAD | 100.00 | 1.43 | 0.098 | 0.641 | 100.00 | 100.00 | 100.00 |

Grind:

| Size (mm) | % WEIGHT |
|---|---|
| +0.25 | 0.20 |
| -0.25+0.15 | 0.64 |
| -0.15+0.075 | 5.83 |
| -0.075+0.045 | 12.36 |
| -0.045 | 80.97 |

The plus 0.25 mm and 0.15 mm fractions are mainly mica minerals

TUNS

Technical University
of Nova Scotia

MINERALS ENGINEERING CENTRE

P.O. Box 1000
Halifax, Nova Scotia
B3J 2X4

Tel: (902) 420-7675
Fax: (902) 425-1037

26 September, 1997

DRD Services Inc.,
101 Shaw Lane
New Maryland, N.B
E3C 1H9

Attention: David Desjardins

Re: Pilot run on nickle ore

CIRCUIT: Ball Mill and Classifier, six rougher cells, two 1st cleaner cells and one 2nd cleaner cell

FEED: 4 kg/min

WATER: Ball Feed: 1.9 L/min
Ball Discharge: 5.0 L/min

REAGENTS: Ball Mill Feed: Sodium Carbonate (10% solution) 3 kg/t
SMQ (5% solution) 0.3 kg/t
SMQ (40% sodium silicate, 40% sodium metphosphate and 20% quberacho)

Flotation Feed Pump: PAX (0.4% solution) 0.075 kg/t
PM230 (0.4% solution) 0.075 kg/t

Rougher Cell #3: PAX (0.4% solution) 0.02 kg/t
PM230 (0.4% solution) 0.02 kg/t

1st Cleaner Cell #1: PAX (0.4% solution) 0.015 kg/t
PM230 (0.4% solution) 0.015 kg/t

SAMPLES: Composited Feed, Final Concentrate and Final Tail were collected every 15 minutes.

| | % | | |
|---|---|---|---|
| PRODUCT | Ni | Co | Cu |
| Flotation Feed | 1.16 | 0.093 | 1.25 |
| Final Concentrate | 2.61 | 0.240 | 4.32 |
| Final Tail | 0.57 | 0.032 | 0.16 |

Cyril Cole

## FLOTATION TEST-1

PURPOSE: TO PRODUCE A ROUGHER CONCENTRATE FROM NICKLE ORE USING ONE STAGE OF ROUGHER FLOTATION

FEED: A 1000 gram sample of ore crushed to minus 4.0 mm by two stages of crushing, jaw and cone.

PROCEDURE: A one stage rougher flotation was carried out. Flotation was carried out in a Denver D12 lab flotation machine. Flotation speed was 1200 RPM. Flotation was carried out at 35% solids after grinding at 66.6% solids for 1/2 hour in rod mill with seven rods. The ore was grounded with 3 kg/t sodium carbonate and 0.3 kg/t SHQ (40% sodium silicate, 40% sodium hexa-metaphosphate and 20% quebracho). All products were filtered, dried, weighed and assayed for nickle, cobalt and copper.

REAGENTS: PAX (4 g/L sol) and Senmin PM230 (4g/L).

| STAGE | TIME (MIN) | REAGENTS ADDED (kg/t) PAX | PM230 | pH |
|---|---|---|---|---|
| CONDITION | 1 | 0.02 | 0.02 | |
| PRIMARY FLOAT | 14 | | | |

| | | % | | | % Distribution | | |
|---|---|---|---|---|---|---|---|
| PRODUCT | % WEIGHT | Ni | Co | Cu | Ni | Co | Cu |
| Rougher CONC | 7.84 | 2.17 | 0.156 | 4.29 | 12.31 | 13.48 | 53.28 |
| ROUGHER TAIL | 92.16 | 1.38 | 0.085 | 0.32 | 87.69 | 86.52 | 46.72 |
| CALCULATED HEAD | 100.00 | 1.38 | 0.091 | 0.63 | 100.00 | 100.00 | 100.00 |

Grind:

| Screen | % WEIGHT |
|---|---|
| +270 | 26.12 |
| -270 | 73.88 |
| | 100.00 |

# FLOTATION TEST-2

PURPOSE: TO PRODUCE A CLEANER CONCENTRATE FROM NICKLE ORE USING TWO STAGES OF ROUGHER FLOTATION

FEED: A 1000 gram sample of ore crushed to minus 4.0 mm by two stages of crushing, jaw and cone.

PROCEDURE: A two stage rougher flotation was carried out, followed by one stage of cleaning on the rougher concentrate. Flotation was carried out in a Denver D12 lab flotation machine. Flotation speeds were 1200 RPM. Flotation was carried out at 35% solids after grinding at 66.6% solids for 3/4 hour in rod mill with seven rods. The ore was grounded with 3 kg/t sodium carbonate and 0.3 kg/t SHQ (40% sodium silicate, 40% sodium hexa-metaphosphate and 20% quebracho). All products were filtered, dried, weighed and assayed for nickle, cobalt and copper.

REAGENTS: PAX (4 g/L sol) and Senmin PM230 (4g/L).

| STAGE | TIME (MIN) | REAGENTS ADDED (kg/t) PAX | PM230 | pH |
|---|---|---|---|---|
| CONDITION | 1 | 0.04 | 0.04 | 7.4 |
| PRIMARY FLOAT | 8 | | | |
| CONDITION | 1 | 0.04 | 0.04 | |
| SECONDARY FLOAT | 6 | | | |
| CLEANER | 8 | | | |

| PRODUCT | % WEIGHT | % Ni | Co | Cu | % Distribution Ni | Co | Cu |
|---|---|---|---|---|---|---|---|
| CLEANER CONC | 8.94 | 5.59 | 0.472 | 6.00 | 35.27 | 45.72 | 86.14 |
| CLEANER TAIL | 18.94 | 2.29 | 0.165 | 0.17 | 30.62 | 33.91 | 5.17 |
| ROUGHER TAIL | 72.12 | 0.67 | 0.026 | 0.075 | 34.11 | 20.37 | 8.69 |
| CALCULATED HEAD | 100.00 | 1.42 | 0.092 | 0.62 | 100.00 | 100.00 | 100.00 |

Grind:

| Screen | % WEIGHT |
|---|---|
| +270 | 5.84 |
| -270 | 94.16 |
| | 100.00 |

49.97
43.37
93.34

66% Ni
80% Co
91% Cu

x 3.6

1.42
48.32

3.3% Ni

Ni recovery low.

# FLOTATION TEST-3

PURPOSE: TO PRODUCE A CLEANER CONCENTRATE FROM NICKLE ORE USING TWO STAGES OF ROUGHER FLOTATION

FEED: A 1000 gram sample of ore crushed to minus 4.0 mm by two stages of crushing, jaw and cone.

PROCEDURE: A two stage rougher flotation was carried out, followed by two stages of cleaning on the rougher concentrate. Flotation was carried out in a Denver D12 lab flotation machine. Flotation speeds were 1200 RPM. Flotation was carried out at 35% solids after grinding at 66.6% solids for 35 min. in rod mill with seven rods. The ore was grounded with 3 kg/t sodium carbonate and 0.3 kg/t SHQ (40% sodium silicate, 40% sodium hexa-metaphoesphate and 20% quebracho). All products were filtered, dried, weighed and assayed for nickle, cobalt and copper.

REAGENTS: PAX (4 g/L sol) and Senmin PM230 (4g/L).

| STAGE | TIME (MIN) | REAGENTS ADDED (kg/t) PAX | PM230 | pH |
|---|---|---|---|---|
| CONDITION | 1 | 0.08 | 0.08 | 7.2 |
| PRIMARY FLOAT | 4 | | | |
| CONDITION | 1 | 0.04 | 0.04 | |
| SECONDARY FLOAT | 8 | | | |
| 1st CLEANER | 4 | | | |
| 2nd CLEANER | 3 | | | |

| PRODUCT | % WEIGHT | % Ni | Co | Cu | % Distribution Ni | Co | Cu |
|---|---|---|---|---|---|---|---|
| CLEANER CONC | 15.66 | 3.90 | 0.315 | 3.35 | 43.24 | 52.56 | 85.36 |
| 2nd CLEANER TAIL | 20.96 | 1.95 | 0.129 | 0.17 | 28.94 | 28.78 | 5.89 |
| 1st CLEANER TAIL | 17.41 | 0.91 | 0.045 | 0.093 | 11.22 | 8.32 | 2.63 |
| ROUGHER TAIL | 45.97 | 0.51 | 0.021 | 0.082 | 16.60 | 10.34 | 6.12 |
| CALCULATED HEAD | 100.00 | 1.41 | 0.094 | 0.62 | 100.00 | 100.00 | 100.00 |

.73 | 36.62
2.78Ni; 72.3%
.21%
81.2% Co
%Cu; 90.4%

Grind:

| Screen | % WEIGHT |
|---|---|
| +270 | 13.62 |
| -270 | 86.38 |
| | 100.00 |

Upgrade factor for
clean conc. + 2nd Cl. Tail.
= X 2.73 (36.62% wt)
2.78% Ni; .21% Co; 1.53% Cu
Recovery: 72.3% Ni.
81.2% Co.
90.4% Cu.

TUNS

Concentrate
~~[illegible]~~ ~ 4:1

impeller of float cell
high blades

UNIMIN
Want Conical
Guelph, Ont. high intensity
conditioner

pyrite kit
cleaner
etc.

PKM

## FLOTATION TEST-4

PURPOSE: TO PRODUCE A CLEANER CONCENTRATE FROM NICKLE ORE USING TWO STAGES OF ROUGHER FLOTATION

FEED: A 1000 gram sample of ore crushed to minus 4.0 mm by two stages of crushing, jaw and cone.

PROCEDURE: A two stage rougher flotation was carried out, followed by two stages of cleaning on the rougher concentrate. Flotation was carried out in a Denver D12 lab flotation machine. Flotation speeds were 1200 RPM. Flotation was carried out at 35% solids after grinding at 66.6% solids for 45 min. in rod mill with seven rods. The ore was grounded with 3 kg/t sodium carbonate and 0.3 kg/t SHQ (40% sodium silicate, 40% sodium hexa-metaphosphate and 20% quebracho). All products were filtered, dried, weighed and assayed for nickle, cobalt and copper.

REAGENTS: PAX (4 g/L sol) and Senmin PM230 (4g/L).

| STAGE | TIME (MIN) | REAGENTS ADDED (kg/t) PAX | PM230 | pH |
|---|---|---|---|---|
| CONDITION | 1 | 0.08 | 0.08 | 7.2 |
| PRIMARY FLOAT | 3 | | | |
| CONDITION | 1 | 0.04 | 0.04 | |
| SECONDARY FLOAT | 10 | | | |
| 1st CLEANER | 4 | | | |
| 2nd CLEANER | 4 | | | |

9.25 {

| PRODUCT | % WEIGHT | % Ni | % Co | % Cu | % Distribution Ni | % Distribution Co | % Distribution Cu |
|---|---|---|---|---|---|---|---|
| CLEANER CONC | 3.70 | 4.88 | 0.392 | 11.24 | 12.78 | 15.43 | 69.22 |
| 2nd CLEANER TAIL | 5.55 | 3.62 | 0.288 | 0.91 | 14.22 | 17.02 | 8.41 |
| 1st CLEANER TAIL | →36.12 | 2.04 | 0.150 | 0.28 | 52.13 | 57.65 | 16.83 |
| ROUGHER TAIL | 54.63 | 0.64 | 0.017 | 0.061 | 20.87 | 9.90 | 5.54 |
| CALCULATED HEAD | 100.00 | 1.41 | 0.094 | 0.60 | 100.00 | 100.00 | 100.00 |

Grind:

| Screen | % WEIGHT |
|---|---|
| +270 | |
| -270 | |

73.68
34.96
108.64

141.

# FLOTATION TEST-5

PURPOSE: TO PRODUCE A CLEANER CONCENTRATE FROM NICKLE ORE USING TWO STAGES OF ROUGHER FLOTATION

FEED: A 1000 gram sample of ore crushed to minus 4.0 mm by two stages of crushing, jaw and cone.

PROCEDURE: A two stage rougher flotation was carried out, followed by three stages of cleaning on the rougher concentrate. Flotation was carried out in a Denver D12 lab flotation machine. Flotation speeds were 1200 RPM. Flotation was carried out at 35% solids after grinding at 66.6% solids for 45 min. in rod mill with seven rods. The ore was grounded with 3 kg/t sodium carbonate and 0.3 kg/t SHQ (40% sodium silicate, 40% sodium hexa-metaphosphate and 20% quebracho). All products were filtered, dried, weighed and assayed for nickle, cobalt and copper.

REAGENTS: PAX (4 g/L sol) and Senmin PM230 (4g/L).

| STAGE | TIME (MIN) | REAGENTS ADDED (kg/t) PAX | PM230 | pH |
|---|---|---|---|---|
| CONDITION | 1 | 0.08 | 0.08 | 7.2 |
| PRIMARY FLOAT | 3 | | | |
| CONDITION | 1 | 0.04 | 0.04 | |
| SECONDARY FLOAT | 6 | | | |
| CONDITION | 1/4 | 0.02 | 0.02 | |
| 1st CLEANER | 4 | | | |
| 2nd CLEANER | 4 | | | |
| 3rd CLEANER | 4 | | | |

| | | % | | | % Distribution | | |
|---|---|---|---|---|---|---|---|
| PRODUCT | % WEIGHT | Ni | Co | Cu | Ni | Co | Cu |
| CLEANER CONC | 5.74 | 4.22 | 0.350 | 8.24 | 15.89 | 19.14 | 77.78 |
| 3rd CLEANER TAIL | 10.65 | 4.00 | 0.299 | 0.56 | 27.96 | 30.29 | 9.80 |
| 2nd CLEANER TAIL | 17.12 | 2.26 | 0.156 | 0.15 | 25.39 | 25.43 | 4.23 |
| 1st CLEANER TAIL | 11.95 | 0.91 | 0.084 | 0.12 | 7.13 | 9.52 | 2.35 |
| ROUGHER TAIL | 54.54 | 0.66 | 0.030 | 0.065 | 23.63 | 15.62 | 5.84 |
| CALCULATED HEAD | 100.00 | 1.52 | 0.105 | 0.61 | 100.00 | 100.00 | 100.00 |

Grind:

| Screen | % WEIGHT |
|---|---|
| +270 | 5.84 |
| -270 | 94.16 |
| | 100.00 |

24.2+42.6+38.7 69.4% Ni x2.98

152

33.51%

$\frac{55.83}{61}$ = 91.5% Cu

$\frac{7.86}{10.6}$ = 74.2% Co

# Appendix C

## CSTR Log Sheets

# CSTR Pilot Trials

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program
Week Ending: 21-Dec-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Total Fe | Ferric |
| | 11:00 AM [ ] | N1A= | 25.0 | 1.17 | 52.3 | | 302.0 | | 12.23% | 15-Dec-97 | 34.66 | 10.96 |
| Mon | 11:00 PM [ ] | N1B = | 25.0 | 1.26 | 52.7 | | 298.0 | | 15.56% | | 35.11 | 20.35 |
| | | N2 = | 25.0 | 1.15 | 53.2 | | 304.0 | | 19.10% | | 52.55 | 28.84 |
| | | N3 = | 0.0 | 1.14 | 53.5 | | 305.0 | | 15.27% | | 29.18 | 14.98 |
| | 11:00 AM [ ] | N1A = | 40.0 | 1.56 | 53.3 | | | | | | 52.43 | 24.71 |
| Tue | 11:00 PM [ ] | N1B = | 40.0 | 1.53 | 53.6 | | | | | | 31.53 | 15.32 |
| | | N2 = | 25.0 | 1.31 | 54.7 | | | | | | 58.02 | 33.76 |
| | | N3 = | 0.0 | 1.26 | 55.2 | | | | | | 50.31 | 32.98 |
| | 11:00 AM [ ] | N1A = | 0.0 | 1.30 | 53.7 | | | | | | 40.70 | 17.78 |
| Wed | 11:00 PM [ ] | N1B = | 0.0 | 1.34 | 54.5 | | | | | | 35.33 | 15.99 |
| | | N2 = | 0.0 | 1.15 | 55.6 | | | | | | 55.12 | 30.07 |
| | | N3 = | 0.0 | 1.19 | 56.2 | | | | | | 43.71 | 28.06 |
| | 11:00 AM [ ] | N1A = | 20.0 | 1.50 | 53.9 | | | | 10.22% | 18-Dec-97 | 47.29 | 27.73 |
| Thu | 11:00 PM [ ] | N1B = | 0.0 | 1.44 | 54.1 | | | | 14.89% | | 44.38 | 32.87 |
| | | N2 = | 0.0 | 1.24 | 54.0 | | | | 17.02% | | 38.68 | 20.57 |
| | | N3 = | 0.0 | 1.10 | 55.2 | | | | 14.96% | | 27.95 | 13.64 |
| | 11:00 AM [ ] | N1A = | 0.0 | 1.36 | 51.4 | | | | | | 44.50 | 24.04 |
| Fri | 11:00 PM [ ] | N1B = | 0.0 | 1.23 | 52.6 | | | | | | 41.81 | 24.60 |
| | | N2 = | 0.0 | 1.17 | 53.3 | | | | | | 19.60 | 25.38 |
| | | N3 = | 0.0 | 1.19 | 54.7 | | | | | | 14.50 | 20.57 |
| | 11:00 AM [ ] | N1A = | 0.0 | | | | | | | | | |
| Sat | 11:00 PM [ ] | N1B = | 0.0 | | | | | | | | | |
| | | N2 = | 0.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| | 11:00 AM [ ] | N1A = | 25.0 | | | | | | | | | |
| Sun | 11:00 PM [ ] | N1B = | 25.0 | | | | | | | | | |
| | | N2 = | 25.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| Totals | | | 275.0 | 25.6 | 1077.7 | | | | | | 797.4 | 463.20 |
| Average | | | 39.29 | 1.28 | 53.9 | | | | | | 49.84 | 28.95 |
| Acid Consumption : | | | 27.2 | kg/m3 | ; | 120.9 | kg acid/tonne concentrate | | | | | |

**Comments:** Stirrers not functioning saturday morning; brushes gone
Circulating pump stopped on Sunday

# CSTR Pilot Trials

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program

Week Ending: 14-Dec-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations Total Fe | Iron Titrations Ferric |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 11:00 AM [ ] | N1A= | 25.0 | 1.43 | 56.3 |  | 308.0 |  | 12.34% | 08-Dec-97 | 43.04 | 19.90 |
| Mon | 11:00 PM [ ] | N1B = | 25.0 | 1.47 | 56.5 |  | 305.0 |  | 15.34% |  | 35.22 | 18.11 |
|  |  | N2 = | 25.0 | 1.34 | 56.7 |  | 303.0 |  | 13.78% |  | 42.93 | 23.81 |
|  |  | N3 = | 0.0 | 1.43 | 56.1 |  | 306.0 |  | 13.44% |  | 41.93 | 28.51 |
|  | 11:00 AM [ ] | N1A = | 35.0 | 1.54 | 57.3 |  |  |  |  |  | 48.41 | 19.01 |
| Tue | 11:00 PM [ ] | N1B = | 40.0 | 1.56 | 59.1 |  |  |  |  |  | 28.17 | 9.95 |
|  |  | N2 = | 35.0 | 1.49 | 59.7 |  |  |  |  |  | 41.93 | 19.34 |
|  |  | N3 = | 0.0 | 1.35 | 59.5 |  |  |  |  |  | 33.88 | 19.79 |
|  | 11:00 AM [ ] | N1A = | 45.0 | 1.67 | 55.7 |  |  |  |  |  | 44.61 | 17.33 |
| Wed | 11:00 PM [ ] | N1B = | 40.0 | 1.53 | 56.4 |  |  |  |  |  | 32.87 | 18.11 |
|  |  | N2 = | 25.0 | 1.37 | 56.0 |  |  |  |  |  | 45.28 | 26.94 |
|  |  | N3 = | 0.0 | 1.27 | 56.2 |  |  |  |  |  | 39.91 | 27.50 |
|  | 11:00 AM [ ] | N1A = | 45.0 | 1.65 | 55.6 |  |  |  | 12.14% | 11-Dec-97 | 42.37 | 17.78 |
| Thu | 11:00 PM [ ] | N1B = | 45.0 | 1.62 | 56.1 |  |  |  | 15.89% |  | 33.99 | 18.45 |
|  |  | N2 = | 25.0 | 1.48 | 56.3 |  |  |  | 13.84% |  | 33.09 | 13.75 |
|  |  | N3 = | 0.0 | 1.46 | 55.3 |  |  |  | 13.51% |  | 34.99 | 21.58 |
|  | 11:00 AM [ ] | N1A = | 25.0 | 1.52 | 55.5 |  |  |  |  |  | 39.47 | 15.65 |
| Fri | 11:00 PM [ ] | N1B = | 25.0 | 1.44 | 55.6 |  |  |  |  |  | 35.11 | 19.23 |
|  |  | N2 = | 25.0 | 1.39 | 56.0 |  |  |  |  |  | 39.80 | 19.68 |
|  |  | N3 = | 0.0 | 1.24 | 56.0 |  |  |  |  |  | 36.00 | 19.57 |
|  | 11:00 AM [ ] | N1A = | 40.0 |  |  |  |  |  |  |  |  |  |
| Sat | 11:00 PM [ ] | N1B = | 40.0 |  |  |  |  |  |  |  |  |  |
|  |  | N2 = | 25.0 |  |  |  |  |  |  |  |  |  |
|  |  | N3 = | 0.0 |  |  |  |  |  |  |  |  |  |
|  | 11:00 AM [ ] | N1A = | 40.0 |  |  |  |  |  |  |  |  |  |
| Sun | 11:00 PM [ ] | N1B = | 40.0 |  |  |  |  |  |  |  |  |  |
|  |  | N2 = | 25.0 |  |  |  |  |  |  |  |  |  |
|  |  | N3 = | 0.0 |  |  |  |  |  |  |  |  |  |
| Totals |  |  | 695.0 | 29.3 | 1131.9 |  |  |  |  |  | 773.0 | 393.99 |
| Average |  |  | 99.29 | 1.46 | 56.6 |  |  |  |  |  | 48.31 | 24.62 |
| Acid Consumption : |  |  | 50.1 | kg/m3 | ; | 222.9 | kg acid/tonne concentrate |  |  |  |  |  |

**Comments:** Power outage (4h) on Sat; lost temperature down to 40 deg C; Hot water heater failure; feeding stopped
Feeding resumed Sun and temperature back to normal

# CSTR Pilot Trials

**Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program**

**Week Ending:** 07-Dec-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Total Fe | Ferric |
| Mon | 11:00 AM [ ] | N1A= | 50.0 | 1.70 | 54.4 | | | | 12.16% | 01-Dec-97 | 54.45 | 24.37 |
| | 11:00 PM [ ] | N1B = | 35.0 | 1.53 | 55.6 | | | | 16.38% | | 37.45 | 20.12 |
| | | N2 = | 25.0 | 1.48 | 56.0 | | | | 15.73% | | 42.60 | 19.23 |
| | | N3 = | 0.0 | 1.52 | 56.4 | | | | 15.64% | | 35.11 | 15.20 |
| Tue | 11:00 AM [ ] | N1A = | 50.0 | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | 50.0 | | | | | | | | | |
| | | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| Wed | 11:00 AM [ ] | N1A = | 50.0 | 1.67 | 54.6 | | | | | | 55.45 | 24.71 |
| | 11:00 PM [ ] | N1B = | 25.0 | 1.51 | 55.8 | | | | | | 33.65 | 15.88 |
| | | N2 = | 35.0 | 1.54 | 56.4 | | | | | | 40.37 | 20.57 |
| | | N3 = | 0.0 | 1.38 | 55.8 | | | | | | 34.66 | 15.84 |
| Thu | 11:00 AM [ ] | N1A = | 40.0 | 1.58 | 54.4 | | | | 12.65% | 04-Dec-97 | 56.91 | 24.60 |
| | 11:00 PM [ ] | N1B = | 25.0 | 1.42 | 55.4 | | | | 15.50% | | 30.30 | 11.74 |
| | | N2 = | 25.0 | 1.40 | 56.0 | | | | 14.95% | | 41.70 | 19.68 |
| | | N3 = | 0.0 | 1.37 | 55.3 | | | | 15.11% | | 34.10 | 15.43 |
| Fri | 11:00 AM [ ] | N1A = | 40.0 | 1.60 | 54.6 | | | | | | 54.67 | 23.37 |
| | 11:00 PM [ ] | N1B = | 25.0 | 1.48 | 56.1 | | | | | | 32.98 | 13.86 |
| | | N2 = | 25.0 | 1.50 | 56.3 | | | | | | 42.26 | 19.34 |
| | | N3 = | 0.0 | 1.46 | 55.8 | | | | | | 34.88 | 15.43 |
| Sat | 11:00 AM [ ] | N1A = | 50.0 | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | 50.0 | | | | | | | | | |
| | | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| Sun | 11:00 AM [ ] | N1A = | 50.0 | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | 50.0 | | | | | | | | | |
| | | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| Totals | | | 850.0 | 24.1 | 888.9 | | | | | | 661.5 | 299.37 |
| Average | | | 121.43 | 1.51 | 55.6 | | | | | | 41.35 | 18.71 |
| Acid Consumption : | | | 62.6 | kg/m3 | ; | 278.2 | kg acid/tonne concentrate | | | | | |

**Comments:** 1. emoved 3 litres of solution from N1A and replaced with K/AMW

# CSTR Pilot Trials

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program

Week Ending: 30-Nov-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Total Fe | Ferric |
| | 11:00 AM [ ] | N1A= | 65.0 | 1.83 | 53.3 | | 310.0 | | 12.00% | 24-Nov-97 | 42.93 | 19.01 |
| Mon | 11:00 PM [ ] | N1B = | 50.0 | 1.77 | 55.1 | | 307.0 | | 16.74% | | 34.77 | 17.33 |
| | 23-Nov-97 | N2 = | 40.0 | 1.52 | 54.9 | | 308.0 | | 14.35% | | 39.35 | 18.22 |
| | | N3 = | 25.0 | 1.65 | 54.3 | | 302.0 | | 13.16% | | 34.43 | 15.88 |
| | 11:00 AM [ ] | N1A = | 50.0 | 1.62 | 53.1 | | | | | | 48.19 | 16.99 |
| Tue | 11:00 PM [ ] | N1B = | 50.0 | 1.72 | 54.8 | | | | | | 43.15 | 22.81 |
| | 24-Nov-97 | N2 = | 40.0 | 1.53 | 54.4 | | | | | | 47.85 | 23.03 |
| | | N3 = | 15.0 | 1.53 | 54.2 | | | | | | 43.83 | 20.01 |
| | 11:00 AM [ ] | N1A = | 40.0 | 1.58 | 53.7 | | | | | | 47.96 | 18.78 |
| Wed | 11:00 PM [ ] | N1B = | 45.0 | 1.62 | 54.8 | | | | | | 36.22 | 17.78 |
| | 25-Nov-97 | N2 = | 25.0 | 1.45 | 55.2 | | | | | | 43.04 | 18.56 |
| | | N3 = | 0.0 | 1.52 | 54.7 | | | | | | 41.03 | 19.57 |
| | 11:00 AM [ ] | N1A = | 40.0 | 1.63 | 55.8 | | | | 12.27% | 27-Nov-97 | 47.63 | 18.78 |
| Thu | 11:00 PM [ ] | N1B = | 50.0 | 1.73 | 56.7 | | | | 16.07% | | 32.65 | 14.98 |
| | 26-Nov-97 | N2 = | 25.0 | 1.50 | 56.9 | | | | 14.08% | | 35.44 | 13.19 |
| | | N3 = | 0.0 | 1.50 | 56.3 | | | | 13.93% | | 37.79 | 17.89 |
| | 11:00 AM [ ] | N1A = | 50.0 | 1.68 | 55.6 | | | | | | 48.52 | 19.23 |
| Fri | 11:00 PM [ ] | N1B = | 50.0 | 1.71 | 56.3 | | | | | | 37.01 | 18.56 |
| | 28-Nov-97 | N2 = | 50.0 | 1.63 | 56.3 | | | | | | 39.80 | 16.21 |
| | | N3 = | 25.0 | 1.60 | 55.1 | | | | | | 38.46 | 17.55 |
| | 11:00 AM [ ] | N1A = | 50.0 | | | | | | | | | |
| Sat | 11:00 PM [ ] | N1B = | 50.0 | | | | | | | | | |
| | 29-Nov-97 | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| | 11:00 AM [ ] | N1A = | 50.0 | | | | | | | | | |
| Sun | 11:00 PM [ ] | N1B = | 50.0 | | | | | | | | | |
| | 30-Nov-97 | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| Totals | | | 1035.0 | 32.3 | 1101.5 | | | | | | 820.1 | 364.35 |
| Average | | | 147.86 | 1.62 | 55.1 | | | | | | 41.00 | 18.22 |
| Acid Consumption : | | | 61.3 | kg/m3 | ; | 408.6 | kg acid/tonne concentrate | | | | | |

**Comments:**

1. Temperature stabilized at 55 deg C
2. Nitrogen increased to 90g per 10 litres of nutrient
3. Feed rate changed to 15d total r.t.; 300g-2l for primaries; 4l slurry for secondaries on Thursday

# CSTR Pilot Trials

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program
Week Ending: 23-Nov-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Total Fe | Ferric |
| | 11:00 AM [ ] | N1A= | 40.0 | 1.53 | 52.1 | | 302.0 | 700 | 12.49% | 17-Nov-97 | 48.07 | 23.14 |
| Mon | 11:00 PM [ ] | N1B = | 35.0 | 1.52 | 53.0 | | 302.0 | 725 | 15.71% | | 40.36 | 20.01 |
| | | N2 = | 25.0 | 1.35 | 53.5 | | 308.0 | 750 | 13.56% | | 45.28 | 22.58 |
| | | N3 = | 15.0 | 1.53 | 52.8 | | 300.0 | 730 | 12.27% | | 34.88 | 13.30 |
| | 11:00 AM [ ] | N1A = | 75.0 | 1.90 | 52.4 | | | | | | 45.84 | 17.66 |
| Tue | 11:00 PM [ ] | N1B = | 70.0 | 1.85 | 53.9 | | | | | | 35.78 | 14.31 |
| | | N2 = | 70.0 | 1.77 | 54.6 | | | | | | 39.24 | 14.42 |
| | | N3 = | 45.0 | 1.71 | 53.8 | | | | | | 44.16 | 18.22 |
| | 11:00 AM [ ] | N1A = | 50.0 | 1.65 | 51.8 | | | | | | 44.50 | 15.43 |
| Wed | 11:00 PM [ ] | N1B = | 50.0 | 1.60 | 54.0 | | | | | | 33.88 | 10.29 |
| | | N2 = | 25.0 | 1.40 | 54.1 | | | | | | 42.60 | 13.97 |
| | | N3 = | 0.0 | 1.46 | 53.9 | | | | | | 46.51 | 19.45 |
| | 11:00 AM [ ] | N1A = | 65.0 | 1.54 | 51.8 | | | | 13.16% | 21-Nov-97 | 49.30 | 23.81 |
| Thu | 11:00 PM [ ] | N1B = | 65.0 | 1.51 | 53.3 | | | | 15.27% | | 33.65 | 14.65 |
| | | N2 = | 50.0 | 1.41 | 53.4 | | | | 13.91% | | 54.78 | 32.09 |
| | | N3 = | 0.0 | 1.44 | 53.2 | | | | 13.65% | | 46.73 | 24.82 |
| | 11:00 AM [ ] | N1A = | 50.0 | 1.58 | 52.7 | | | | | | 51.76 | 27.50 |
| Fri | 11:00 PM [ ] | N1B = | 50.0 | 1.55 | 54.2 | | | | | | 34.43 | 13.75 |
| | | N2 = | 0.0 | 1.36 | 54.7 | | | | | | 51.99 | 28.29 |
| | | N3 = | 0.0 | 1.44 | 54.2 | | | | | | 47.18 | 26.94 |
| | 11:00 AM [ ] | N1A = | 50.0 | | | | | | | | | |
| Sat | 11:00 PM [ ] | N1B = | 50.0 | | | | | | | | | |
| | | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| | 11:00 AM [ ] | N1A = | 50.0 | | | | | | | | | |
| Sun | 11:00 PM [ ] | N1B = | 50.0 | | | | | | | | | |
| | | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| Totals | | | 1080.0 | 31.1 | 1067.4 | | | | | | 870.9 | 394.63 |
| Average | | | 154.29 | 1.56 | 53.4 | | | | | | 43.55 | 19.73 |
| Acid Consumption : | | | 54.4 | kg/m3 | ; | 362.6 | kg acid/tonne concentrate | | | | | |

**Comments;**

1. Temperature increased 1 deg C
2. Colour more black in primaries as T increased
3. Counts have decreased

# CSTR Pilot Trials

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program

Week Ending: 16-Nov-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations Total Fe | Ferric |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11:00 AM [] | N1A= | 75.0 | 1.83 | 51.5 | | 314.0 | 710 | 13.72% | 10-Nov-97 | 51.20 | 27.50 |
| Mon | 11:00 PM [] | N1B = | 75.0 | 1.91 | 51.9 | | 315.0 | 730 | 15.93% | | 50.76 | 31.19 |
| | | N2 = | 75.0 | 1.83 | 52.9 | | 309.0 | 750 | 13.03% | | 51.20 | 28.62 |
| | | N3 = | 40.0 | 1.71 | 52.9 | | 307.0 | 700 | 12.41% | | 56.24 | 34.66 |
| | 11:00 AM [] | N1A = | 40.0 | 1.85 | 51.1 | | | | | | 53.11 | 27.84 |
| Tue | 11:00 PM [] | N1B = | 45.0 | 1.72 | 51.9 | | | | | | 47.29 | 24.48 |
| | | N2 = | 35.0 | 1.54 | 52.0 | | | | | | 51.54 | 27.73 |
| | | N3 = | 0.0 | 1.49 | 52.3 | | | | | | 47.96 | 21.91 |
| | 11:00 AM [] | N1A = | 75.0 | 1.75 | 52.7 | | | | | | 57.35 | 29.63 |
| Wed | 11:00 PM [] | N1B = | 60.0 | 1.80 | 53.5 | | | | | | 38.68 | 16.10 |
| | | N2 = | 60.0 | 1.77 | 52.9 | | | | | | 52.21 | 26.16 |
| | | N3 = | 25.0 | 1.61 | 53.3 | | | | | | 43.94 | 19.79 |
| | 11:00 AM [] | N1A = | 55.0 | 1.65 | 52.6 | | | | 13.54% | 13-Nov-97 | 41.37 | 16.43 |
| Thu | 11:00 PM [] | N1B = | 60.0 | 1.77 | 53.5 | | | | 15.34% | | 40.70 | 20.57 |
| | | N2 = | 60.0 | 1.73 | 54.1 | | | | 12.63% | | 55.34 | 32.53 |
| | | N3 = | 25.0 | 1.56 | 53.4 | | | | 11.72% | | 34.10 | 14.87 |
| | 11:00 AM [] | N1A = | 75.0 | 1.59 | 52.4 | | | | | sample for N | 48.86 | 19.79 |
| Fri | 11:00 PM [] | N1B = | 75.0 | 1.69 | 53.6 | | | | | assay; Counts | 45.95 | 20.91 |
| | | N2 = | 75.0 | 1.64 | 54.0 | | | | | N1A - 170K | 63.17 | 34.77 |
| | | N3 = | 25.0 | 1.52 | 53.3 | | | | | N2 - 450K | 54.89 | 31.86 |
| | 11:00 AM [] | N1A = | 50.0 | | | | | | | | | |
| Sat | 11:00 PM [] | N1B = | 50.0 | | | | | | | | | |
| | | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| | 11:00 AM [] | N1A = | 50.0 | | | | | | | | | |
| Sun | 11:00 PM [] | N1B = | 50.0 | | | | | | | | | |
| | | N2 = | 50.0 | | | | | | | | | |
| | | N3 = | 0.0 | | | | | | | | | |
| Totals | | | 1355.0 | 34.0 | 1055.8 | | | | | | 985.9 | 507.34 |
| Average | | | 193.57 | 1.70 | 52.8 | | | | | | 49.29 | 25.37 |
| Acid Consumption : | | | 69.5 | kg/m3 | ; | 463.6 | kg acid/tonne concentrate | | | | | |

## Comments:

1. Temperature to increase 1 deg C
2. Recycle solution diluted again this week
3. Nov. 11 - Air turned up
4. Solution changing colour with higher T and increased N addition

# CSTR Pilot Trials

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program
Week Ending: 09-Nov-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  |  | Total Fe | Ferric |
| Mon | 11:00 AM [ ] | N1A= | 25.0 | 1.42 | 50.1 |  |  |  | 13.51% | 03-Nov-97 | 50.87 | 24.37 |
|  | 11:00 PM [ ] | N1B = | 50.0 | 1.63 | 50.9 |  |  |  | 14.28% |  | 47.18 | 24.15 |
|  |  | N2 = | 25.0 | 1.49 | 51.4 |  |  |  | 12.00% |  | 44.94 | 23.93 |
|  |  | N3 = | 0.0 | 1.34 | 51.1 |  |  |  | 12.12% |  | 43.83 | 28.62 |
| Tue | 11:00 AM [ ] | N1A = | 90.0 | 1.71 | 49.8 |  |  |  |  | Counts 1A/N2 | 47.74 | 16.88 |
|  | 11:00 PM [ ] | N1B = | 100.0 | 1.85 | 50.6 |  |  |  |  | TKN on N1A | 46.17 | 18.78 |
|  |  | N2 = | 120.0 | 1.76 | 51.4 |  |  |  |  |  | 44.05 | 17.55 |
|  |  | N3 = | 40.0 | 1.63 | 51.2 |  |  |  |  |  | 35.78 | 18.34 |
| Wed | 11:00 AM [ ] | N1A = | 50.0 |  |  |  |  |  |  |  |  |  |
|  | 11:00 PM [ ] | N1B = | 50.0 |  |  |  |  |  |  |  |  |  |
|  |  | N2 = | 50.0 |  |  |  |  |  |  |  |  |  |
|  |  | N3 = | 0.0 |  |  |  |  |  |  |  |  |  |
| Thu | 11:00 AM [ ] | N1A = | 115.0 | 1.65 | 50.7 |  |  |  | 12.91% | 06-Nov-97 | 47.29 | 20.57 |
|  | 11:00 PM [ ] | N1B = | 115.0 | 1.77 | 52.0 |  |  |  | 14.62% |  | 32.76 | 9.61 |
|  |  | N2 = | 100.0 | 1.62 | 50.8 |  |  |  | 12.92% |  | 38.68 | 13.75 |
|  |  | N3 = | 50.0 | 1.58 | 52.2 |  |  |  | 12.12% |  | 35.66 | 17.79 |
| Fri | 11:00 AM [ ] | N1A = | 40.0 | 1.57 | 51.1 |  |  |  |  |  | 48.30 | 22.53 |
|  | 11:00 PM [ ] | N1B = | 40.0 | 1.69 | 51.8 |  |  |  |  |  | 41.03 | 20.12 |
|  |  | N2 = | 25.0 | 1.54 | 52.3 |  |  |  |  |  | 44.27 | 20.12 |
|  |  | N3 = | 25.0 | 1.55 | 51.4 |  |  |  |  |  | 48.97 | 28.84 |
| Sat | 11:00 AM [ ] | N1A = | 50.0 |  |  |  |  |  |  |  |  |  |
|  | 11:00 PM [ ] | N1B = | 50.0 |  |  |  |  |  |  |  |  |  |
|  |  | N2 = | 0.0 |  |  |  |  |  |  |  |  |  |
|  |  | N3 = | 0.0 |  |  |  |  |  |  |  |  |  |
| Sun | 11:00 AM [ ] | N1A = | 50.0 |  |  |  |  |  |  |  |  |  |
|  | 11:00 PM [ ] | N1B = | 50.0 |  |  |  |  |  |  |  |  |  |
|  |  | N2 = | 0.0 |  |  |  |  |  |  |  |  |  |
|  |  | N3 = | 0.0 |  |  |  |  |  |  |  |  |  |
| Totals |  |  | 1310.0 | 25.8 | 818.8 |  |  |  |  |  | 697.5 | 325.95 |
| Average |  |  | 187.14 | 1.61 | 51.2 |  |  |  |  |  | 43.60 | 20.37 |
| Acid Consumption : |  |  | 64.1 | kg/m3 | ; | 427.5 | kg acid/tonne ore |  |  |  |  |  |

**Comments:**

1. Nitrogen and phosphate addtion doubled on Monday and Tuesday
2. Recycle solution diluted on Tuesday to reduce iron to 10 gpl
3. Temperature incresed by 1 deg C

# CSTR Pilot Trials

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program

**Week Ending:** 31-Oct-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Total Fe | Ferric |
| | 11:00 AM [] | N1A= | 30.0 | 1.97 | 48.9 | | | | 15.25% | 27-Oct-97 | 30.75 | 16.32 |
| Mon | 11:00 PM [] | N1B = | 30.0 | 2.04 | 49.1 | | | | 16.86% | | 32.53 | 22.14 |
| | | N2 = | 25.0 | 1.81 | 49.3 | | | | 15.34% | | 22.02 | 9.61 |
| | | N3 = | 5.0 | 1.59 | 49.5 | | | | 12.39% | | 23.03 | 12.52 |
| | 11:00 AM [] | N1A = | 60.0 | 1.99 | 49.4 | | | | | | 36.11 | 24.26 |
| Tue | 11:00 PM [] | N1B = | 50.0 | 2.07 | 49.3 | | | | | | 35.33 | 25.83 |
| | | N2 = | 40.0 | 1.79 | 51.2 | | | | | | 28.40 | 18.22 |
| | | N3 = | 15.0 | 1.52 | 20.6 | | | | | | 27.84 | 18.45 |
| | 11:00 AM [] | N1A = | 50.0 | 1.84 | 49.7 | | | | | | 37.23 | 20.01 |
| Wed | 11:00 PM [] | N1B = | 50.0 | 1.86 | 50.6 | | | | | | 32.65 | 19.68 |
| | | N2 = | 50.0 | 1.67 | 51.7 | | | | | | 30.30 | 15.99 |
| | | N3 = | 0.0 | 1.38 | 50.7 | | | | | | 26.27 | 15.88 |
| | 11:00 AM [] | N1A = | 75.0 | 1.77 | 49.9 | | 318.6 | | 14.00% | 30-Oct-97 | 38.35 | 19.34 |
| Thu | 11:00 PM [] | N1B = | 75.0 | 1.80 | 51.9 | | 320.3 | | 15.50% | | 31.75 | 16.32 |
| | | N2 = | 40.0 | 1.61 | 51.9 | | 310.5 | | 13.71% | | 30.97 | 15.32 |
| | | N3 = | 0.0 | 1.45 | 51.0 | | 303.4 | | 13.50% | | 25.38 | 14.42 |
| | 11:00 AM [] | N1A = | 75.0 | 1.68 | 49.5 | | | | | | 41.14 | 24.04 |
| Fri | 11:00 PM [] | N1B = | 75.0 | 1.75 | 50.0 | | | | | | 33.88 | 17.22 |
| | | N2 = | 65.0 | 1.63 | 51.4 | | | | | | 33.20 | 16.43 |
| | | N3 = | 0.0 | 1.45 | 50.0 | | | | | | 29.96 | 17.55 |
| | 11:00 AM [] | N1A = | 50.0 | 1.40 | 50.1 | | | | | | 44.27 | 23.70 |
| Sat | 11:00 PM [] | N1B = | 50.0 | 1.48 | 50.9 | | | | | | 41.59 | 23.03 |
| | | N2 = | 50.0 | 1.43 | 51.2 | | | | | | 39.58 | 21.35 |
| | | N3 = | 25.0 | 1.50 | 50.3 | | | | | | 33.43 | 19.45 |
| | 11:00 AM [] | N1A = | 25.0 | 1.48 | 50.3 | | | | | | | |
| Sun | 11:00 PM [] | N1B = | 25.0 | 1.38 | 50.6 | | | | | | | |
| | | N2 = | 0.0 | 1.45 | 51.5 | | | | | | | |
| | | N3 = | 0.0 | 1.40 | 50.3 | | | | | | | |
| Totals | | | 1035.0 | 46.2 | 1380.8 | | | | | | 786.0 | 447.08 |
| Average | | | 147.86 | 1.65 | 49.3 | | | | | | 32.75 | 18.63 |
| Acid Consumption : | | | 57.2 | kg/m3 | ; | 381.1 | kg acid/tonne ore | | | | | |

**Comments:**

1. pH on tanks drifting up to 1.9 each night except for N3
2. temperature increased by 1-2 deg C to +50 deg C
3. pH adj. to 1.4 and extra acid to pH=1.0 added to feed tank to correct drifting to 1.9
4. N-Ft: 50 litres solution/ 325 mls of acid

# CSTR Pilot Trials

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program

**Week Ending:** 24-Oct-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations Total Fe | Iron Titrations Ferric |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11:00 AM [ ] | N1A= | 25.0 | 1.51 | 48.2 | | 300.6 | 700 | 15.20% | 20-Oct-97 | 40.81 | 29.85 |
| Mon | 11:00 PM [ ] | N1B = | 30.0 | 1.46 | 48.5 | | 303.0 | 750 | 16.23% | | 26.50 | 18.89 |
| | | N2 = | 20.0 | 1.44 | 48.0 | | 305.0 | 790 | 16.10% | | 36.78 | 24.26 |
| | | N3 = | 0.0 | 1.43 | 48.3 | | 305.0 | 780 | 15.71% | | 28.06 | 15.43 |
| | 11:00 AM [ ] | N1A = | 25.0 | 1.51 | 47.8 | | | | | | 31.75 | 17.78 |
| Tue | 11:00 PM [ ] | N1B = | 30.0 | 1.47 | 48.1 | | | | | | 26.16 | 16.21 |
| | | N2 = | 15.0 | 1.50 | 49.3 | | | | | | 23.14 | 7.71 |
| | | N3 = | 0.0 | 1.46 | 48.6 | | | | | | 41.37 | 26.16 |
| | 11:00 AM [ ] | N1A = | 0.0 | 1.57 | 48.7 | | | | | | 33.54 | 20.12 |
| Wed | 11:00 PM [ ] | N1B = | 0.0 | 1.55 | 48.9 | | | | | | 27.84 | 18.22 |
| | | N2 = | 0.0 | 1.52 | 49.3 | | | | | | 31.86 | 18.22 |
| | | N3 = | 0.0 | 1.50 | 49.1 | | | | | | 33.88 | 19.57 |
| | 11:00 AM [ ] | N1A = | 35.0 | 1.48 | 47.5 | | | | 15.19% | 23-Oct-97 | 35.89 | 23.37 |
| Thu | 11:00 PM [ ] | N1B = | 35.0 | 1.47 | 47.8 | | | | 15.94% | | 28.51 | 18.78 |
| | | N2 = | 20.0 | 1.51 | 48.9 | | | | 16.43% | | 40.81 | 28.51 |
| | | N3 = | 0.0 | 1.52 | 48.9 | | | | 14.71% | | 30.30 | 19.01 |
| | 11:00 AM [ ] | N1A = | 25.0 | 1.46 | 48.0 | | | | | | 38.01 | 24.26 |
| Fri | 11:00 PM [ ] | N1B = | 30.0 | 1.43 | 48.7 | | | | | | 29.63 | 17.44 |
| | | N2 = | 15.0 | 1.50 | 49.1 | | | | | | 38.24 | 24.82 |
| | | N3 = | 0.0 | 1.51 | 49.3 | | | | | | 33.88 | 23.25 |
| | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| Sat | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| Sun | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Totals | | | 305.0 | 29.8 | 971.0 | | | | | | 657.0 | 411.86 |
| Average | | | 43.57 | 1.49 | 48.6 | | | | | | 32.85 | 20.59 |
| Acid Consumption : | | | 15.2 | kg/m3 | ; | 101.1 | kg acid/tonne ore | | | | | |

**Comments:**

1. Solution overflow recycle started at est. 30% (10 gpl Fe) started on 20-Oct-97
2. Cell count 7M for N1A on 24-Oct-97; 3 different sizes of rods

# CSTR Pilot Trials

**Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program**
**Week Ending:** 17-Oct-97

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Total Fe | Ferric |
| Mon | 11:00 AM [ ] | N1A= | 35.0 | 1.50 | 48.5 | | 308.6 | | 16.84% | 13-Oct-97 | 32.09 | 20.12 |
| | 11:00 PM [ ] | N1B = | 45.0 | 1.47 | 48.3 | | 308.1 | | 16.91% | | 26.27 | 19.57 |
| | | N2 = | 25.0 | 1.45 | 48.7 | | 309.7 | | | | 25.71 | 12.75 |
| | | N3 = | 10.0 | 1.46 | 48.2 | | 308.6 | | | | 25.83 | 11.96 |
| Tue | 11:00 AM [ ] | N1A = | 30.0 | 1.48 | 48.1 | | | | | | 21.91 | 10.73 |
| | 11:00 PM [ ] | N1B = | 35.0 | 1.46 | 48.5 | | | | | | 14.65 | 7.83 |
| | | N2 = | 25.0 | 1.46 | 49.3 | | | | | | 28.62 | 14.87 |
| | | N3 = | 0.0 | 1.52 | 48.8 | | | | | | 31.30 | 17.78 |
| Wed | 11:00 AM [ ] | N1A = | 5.0 | 1.48 | 48.0 | | | | | | 25.94 | 13.08 |
| | 11:00 PM [ ] | N1B = | 10.0 | 1.43 | 48.5 | | | | | | 20.79 | 13.08 |
| | | N2 = | 0.0 | 1.53 | 48.9 | | | | | | 30.63 | 16.92 |
| | | N3 = | 0.0 | 1.52 | 49.1 | | | | | | 33.88 | 22.70 |
| Thu | 11:00 AM [ ] | N1A = | 30.0 | 1.48 | 48.2 | | | | 12.07% | 16-Oct-97 | 32.98 | 18.56 |
| | 11:00 PM [ ] | N1B = | 35.0 | 1.46 | 48.0 | | | | 13.84% | | 37.23 | 28.84 |
| | | N2 = | 25.0 | 1.47 | 49.2 | | | | 13.44% | | 42.60 | 27.84 |
| | | N3 = | 0.0 | 1.52 | 48.7 | | | | 11.64% | | 36.45 | 27.39 |
| Fri | 11:00 AM [ ] | N1A = | 30.0 | 1.50 | 48.1 | | | | | | 28.06 | 18.56 |
| | 11:00 PM [ ] | N1B = | 35.0 | 1.49 | 48.3 | | | | | | 29.40 | 22.02 |
| | | N2 = | 20.0 | 1.51 | 49.4 | | | | | | 25.04 | 13.19 |
| | | N3 = | 0.0 | 1.46 | 49.6 | | | | | | 34.77 | 25.60 |
| Sat | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Sun | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Totals | | | 395.0 | 29.7 | 972.4 | | | | | | 584.2 | 363.39 |
| Average | | | 56.43 | 1.48 | 48.6 | | | | | | 29.21 | 18.17 |
| Acid Consumption : | | | 20.9 kg/m3 | | ; | 139.5 kg acid/tonne ore | | | | | | |

**Comments:** Please record any changes or problems experienced during operations

1. Colour change noted in N3 overflow solution; turned brown from green after w/e; Oct13/14
2. 30 litre tank set up with 1/3 overflow solution to 2/3 AMW with nutrient for recycle; est. start date: Oct. 20-22 split based on est. 10gpl total Fe in recycle.
3. Added to Ft 30 litre AMW; 60 mls acid; equivalent to 12 mls/d added to tank

St. Stephen Nickel Mines

Weekly Log Sheet - N Series; 15 Litre Bacterial Oxidation Pilot Plant Program
**Week Ending:** ______________

| Day | Feed Times | Tank # | Daily Acid (ml) | pH | Temp. deg C | DO | ORP | RPM's | % Solids | Samples for Assay | Iron Titrations | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Total Fe | Ferric |
| Monday | 11:00 AM [ ] | N1A= | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Tuesday | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Wednesday | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Thursday | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Friday | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Saturday | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Sunday | 11:00 AM [ ] | N1A = | | | | | | | | | | |
| | 11:00 PM [ ] | N1B = | | | | | | | | | | |
| | | N2 = | | | | | | | | | | |
| | | N3 = | | | | | | | | | | |
| Totals | | | 0.0 | 0.0 | 0.0 | | | | | | | |
| Average | | | 0.00 | 0.00 | 0.0 | | | | | | | |
| Acid Consumption : | | | 0.0 | kg/m3 | | | | | | | | |

**Comments:** Please record any changes or problems experienced durjng operations

# Appendix D

## Flowsheet Development - Test Protocols

# Table D1

**Test ID:** **Test #1: NT1 - Acid Pre-Leach**

**Objective:** To determine degree of oxidation via acid leachable metals

**Conditions:**

Volume: 10 litres
Solids Loading: 15%; 1.5 kg
Temperature: 50 deg C
pH: 1.4
Agitation: 750 RPM
Feed: TUNS Concentrate
Sampling: Head Sample; 100 ml slurry at 3h & 24h

**Procedure:**

1. Add 1500g of Concentrate to 10 litres AMW and adjust and maintain pH at 1.4
2. Agitate slurry and record acid addition; take head sample of concentrate for assay
3. After 3h take a 500ml slurry sample, filter, determine solids % and keep solid sample for assay; titrate solution
4. Run test for 24h and sample slurry for solids % and assay, and solution titration

---

**Test ID:** **Test #2: NT2 - O/F Pre-Leach**

**Objective:** To determine amount of concentrate required for ferric reduction

**Conditions:**

Volume: 10 litres
Solids Loading: 5%; 10%; 15%
Temperature: 50 deg C
pH: 1.4 - 1.5
Agitation: 750 RPM
Feed: TUNS Concentrate added to filtered N3 overflow solution
Sampling: Head Sample; solution for titration each hour

**Procedure:**

1. Add 500g of Concentrate to 4 litres N3 O/F and adjust and maintain pH at 1.4
2. Titrate O/F solution before start to determine ferric ion
3. Agitate slurry and record acid addition; take head sample of concentrate for assay
4. After 1h take a 100ml slurry sample, filter, titrate solution; monitor ferric
5. Keep adding 5% solids each hour until ferric ion drops to 1-2 gpl; record solids addition

---

**Test ID:** **Test #3: NT3 - Iron Precipitation on N3 O/F**

**Objective:** To determine conditions for iron precipitation and effect on Cu,Ni,Co

**Conditions:**

Volume: 10 litres
Solids Loading: none; 10% lime slurry pre-mixed in separate tank
Temperature: 50 deg C
pH: to 4.0
Agitation: 750 RPM
Feed: Lime
Sampling: Solution before and after pH adjustment

**Procedure:**

1. Slowly add lime slurry to N3 O/F and monitor pH, over 2h log lime addition to reach pH 3.0
2. Take solution samples every hour for titration; determine pH that eliminates iron in solution
3. Take solution samples for Ni, Co, Fe, and Cu assay
4. hold at pH at 0.5 intervals for 1h before each addtion

## Table D2. Test Protocol - NT4 to NT6

**Test ID:** **Test #4: NT4 - Acid Pre-Leach (Repeat of NT1)**
**Objective:** To determine degree of oxidation via acid leachable metals
**Conditions:**

Volume: 2 litres
Solids Loading: 10%; 200 g
Temperature: 50 deg C
pH: 1.0 - 1.4
Agitation: 750 RPM
Feed: Fresh Core Sample
Sampling: Head Sample; Solution & Solids
Time: 3h

**Procedure:**

1. Add 200g of fresh ore to 2 litres AMW and adjust and maintain pH at <1.4
2. Agitate slurry and record acid addition to maintain pH; take head sample of ore for assay
3. After 3h filter the entire sample, determine solids % and keep solid sample for assay; titrate and assay solution

---

**Test ID:** **Test #5: NT5 - O/F Pre-Leach**
**Objective:** To determine effectiveness of pre-leach at higher temperature
**Conditions:**

Volume: 3 litres
Solids Loading: 15%, 3 additions of 150g
Temperature: +85 deg C
pH: 1.0 - 1.2
Agitation: 750 RPM
Feed: TUNS Concentrate added to filtered N3 overflow solution
Sampling: Head Sample, solution for titration each hour
Time: 3h

**Procedure:**

1. Add 150g of Concentrate to 3 litres N3 O/F and adjust and maintain pH at <1.2
2. Titrate O/F solution before start to determine ferric ion
3. Agitate slurry and record acid addition; take head sample of concentrate for assay
4. After 3h filter slurry and titrate solution; monitor ferric ion
5. Determine final solids %

---

**Test ID:** **Test #6: NT6 - Sodium Sulphide Precipitation**
**Objective:** To determine the effectiveness of metal removal
**Conditions:**

Volume: 2 litres
Solids Loading:
Temperature: 50 deg C
pH: 1.0 - 1.2
Agitation: 750 RPM
Feed: Na2S flake
Sampling: Head Sample; solution for titration after test
Time: 30 min

**Procedure:**

1. Add Na2S flake periodically
2. Titrate O/F solution before start to determine ferric ion and assay for metal loading
4. After completion filter slurry and assay solution for metals and titrate for iron

---

# Table D3. Test Results for NT4 to NT6

## NT4 - Acid Pre-leach on Fresh Ore @ pH <1.4 and 50 deg C

**Results**

1. 7 mls sulphuric acid added
2. Solid % decreased from 10% to 8.86%
3. Titration Results: Total Iron = 20.12gpl; Ferric Ion = 13.19 gpl
4. Solution Assays: 0.02 ppm Cu; 10 ppm Ni; 0.02 ppm Co; 6420 ppm Fe
5. 1.54% Fe; 0% Cu; 0.04% Ni; 0.01% Co leached in 3h test

## NT5 - Ferric Leach with O/F from Pilot @+85 deg C

**Results**

1. 20 mls sulphuric acid added
2. Solid % decreased from 15% to 13.15%
3. Titration Results: Total Iron = 72.33 from 61.83gpl; Ferric Ion = 25.04 from 41.14 gpl
4. Solution Assays: 450 ppm Cu; 560 ppm Ni; 47 ppm Co; 19470 ppm Fe
5. 15.2% Fe; 7.8% Cu; 16.9% Ni; 16.5% Co leached in 3h test

## NT6 - Sodium Sulphide Precipitation @ 50 deg C

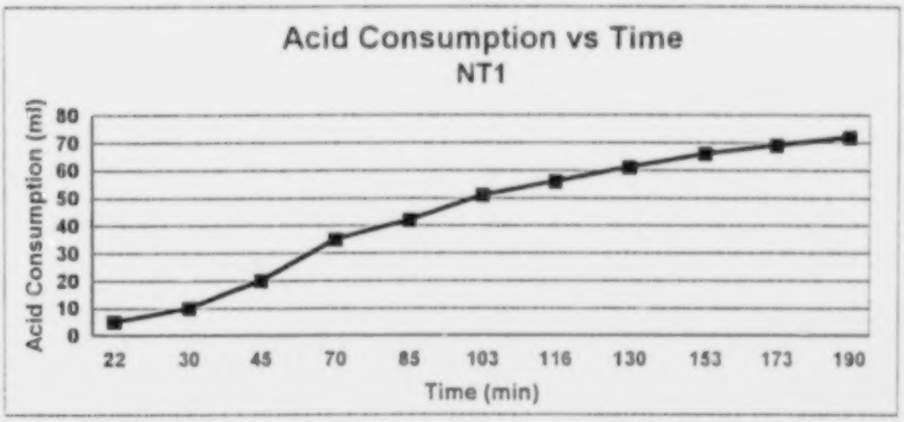
**Results**

1. Determined that Na2S is soluble
2. pH and temperature increased rapidly; sample taken after 30 min
3. Titration Results: Total Iron = 45.06 gpl; Ferric Ion = 6.71 gpl
4. Solution Assays: 0.67 from 6180 ppm Cu; 576 from 3970 ppm Ni; 45 from 365 ppm Co; 32320 from 33500ppm Fe
5. 3.5% Fe; 99.98% Cu; 85.5% Ni; 87.7% Co precipitated in 30 min. test

# Figure D1. Acid Pre-Leach: NT1

NT1 - Acid Pre-leach Trials @ pH=1.4

|  | Fe | Cu | Ni | Co |
|---|---|---|---|---|
| **Solution Assays** | 8760 | 350 | 824 | 63 |
| **Calculated Max.** | 59400 | 5325 | 2895 | 247.5 |
| **% Metal Leached** | 14.75% | 6.57% | 28.46% | 25.45% |



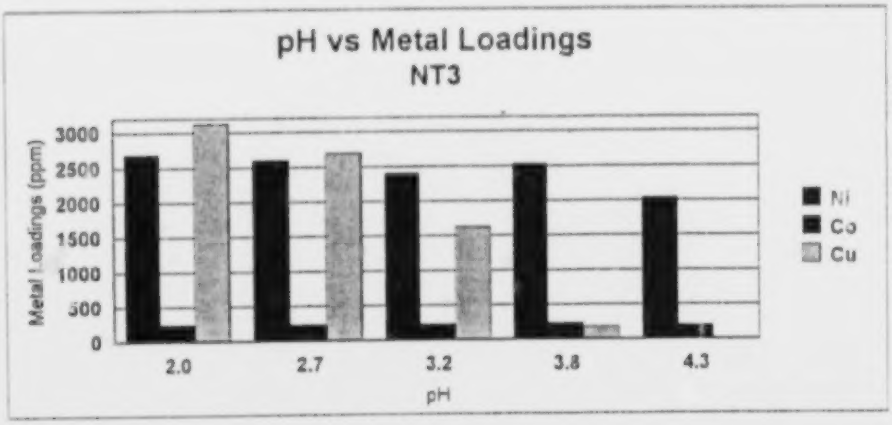
# Figure D2. Lime Precipitation Trials

## NT3 - Lime Precipitation Trials

| pH | Fe | Cu | Ni | Co |
|---|---|---|---|---|
| 2.0 | 12480 | 3130 | 2690 | 248 |
| 2.7 | 10120 | 2700 | 2610 | 239 |
| 3.2 | 9120 | 1630 | 2400 | 230 |
| 3.8 | 7760 | 184 | 2530 | 244 |
| 4.3 | 6560 | 4 | 2040 | 205 |

**Percent Metal Losses =**

| Fe | Cu | Ni | Co | |
|---|---|---|---|---|
| 47.44% | 99.87% | 24.16% | 17.34% | @ pH=4.3 |
| 37.82% | 94.12% | 5.95% | 1.61% | @ pH=3.8 |



# Appendix E

## A Preliminary Financial Model

# St. STEPHEN NICKEL PROJECT
# (150,000 TPY) Value Added
## Production Summary

12/10/97

| Year | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | End |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tons Mined | | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | - | - | - | - | - | - |
| Tons Milled | | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | - | - | - | - | - | - |
| Cumulative | | 150,000 | 300,000 | 450,000 | 600,000 | 750,000 | 750,000 | 750,000 | 750,000 | 750,000 | 750,000 | 750,000 |
| Concentrate Produced Tons | Ni | 1,986 | 1,986 | 1,986 | 1,986 | 1,986 | - | - | - | - | - | - |
| | Co | 227 | 227 | 227 | 227 | 227 | - | - | - | - | - | - |
| | Cu | 714 | 714 | 714 | 714 | 714 | - | - | - | - | - | - |
| | | | | | | | | | | | | |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |
| Metal Produced Tons | Ni | 993 | 993 | 993 | 993 | 993 | - | - | - | - | - | - |
| | Co | 114 | 114 | 114 | 114 | 114 | - | - | - | - | - | - |
| | Cu | 571 | 571 | 571 | 571 | 571 | - | - | - | - | - | - |
| | | | | | | | | | | | | |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |

# St. STEPHEN NICKEL PROJECT
## (150,000 TPY) Value Added

| | | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Yr 10 | End |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ore Milled (Tons) | | 150,000 | 150,000 | 150,000 | 150,000 | 150,000 | - | - | - | - | - | - |
| Cumulative | | 150,000 | 300,000 | 450,000 | 600,000 | 750,000 | 750,000 | 750,000 | 750,000 | 750,000 | 750,000 | 750,000 |
| Head Grade | % Ni | 0.95% | 0.95% | 0.95% | 0.95% | 0.95% | 0.95% | 0.95% | 0.95% | 0.95% | 0.95% | 0.95% |
| | % Co | 0.09% | 0.09% | 0.09% | 0.09% | 0.09% | 0.09% | 0.09% | 0.09% | 0.09% | 0.09% | 0.09% |
| | % Cu | 0.47% | 0.47% | 0.465% | 0.465% | 0.465% | 0.465% | 0.465% | 0.465% | 0.465% | 0.465% | 0.465% |
| | | | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |
| Recovery Processing | % Ni | 69.9% | 69.9% | 69.9% | 69.9% | 69.9% | 69.9% | 69.9% | 69.9% | 69.9% | 69.9% | 69.9% |
| | % Co | 80.2% | 80.2% | 80.2% | 80.2% | 80.2% | 80.2% | 80.2% | 80.2% | 80.2% | 80.2% | 80.2% |
| | % Cu | 81.8% | 81.8% | 81.8% | 81.8% | 81.8% | 81.8% | 81.8% | 81.8% | 81.8% | 81.8% | 81.8% |
| | | | | | | | | | | | | |
| | | | - | - | - | - | - | - | - | - | - | - |
| | | | - | - | - | - | - | - | - | - | - | - |
| Concentrate Grade | % Ni | 50.00% | 50.00% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% |
| | % Co | 50.00% | 50.00% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% |
| | % Cu | 80.00% | 80.00% | 80.0% | 80.0% | 80.0% | 80.0% | 80.0% | 80.0% | 80.0% | 80.0% | 80.0% |
| | | | | | | | | | | | | |
| | | 0.00% | 0.00% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| | | 0.00% | 0.00% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Concentrate Production (Dry Tons) | Ni | 1,986 | 1,986 | 1,986 | 1,986 | 1,986 | - | - | - | - | - | - |
| | Co | 227 | 227 | 227 | 227 | 227 | - | - | - | - | - | - |
| | Cu | 714 | 714 | 714 | 714 | 714 | - | - | - | - | - | - |
| | | | | | | | | | | | | |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |
| Concentrate Contained Metal (Dry Tons) | Ni | 993 | 993 | 993 | 993 | 993 | - | - | - | - | - | - |
| | Co | 114 | 114 | 114 | 114 | 114 | - | - | - | - | - | - |
| | Cu | 571 | 571 | 571 | 571 | 571 | - | - | - | - | - | - |
| | | | | | | | | | | | | |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |

## OPERATING COST SUMMARY

| OPERATING COSTS | |
|---|---|
| **Contract Mine Operating Costs** | |
| | |
| Labour | $0.00 |
| Materials & Supply | $0.00 |
| Equipment Operations | $0.00 |
| **Total Mine** | $50.00 |
| | $0.00 |
| | $0.00 |
| | $0.00 |
| | $0.00 |
| **Total Mine Operating** | **$50.00** |
| | |
| **Mill Operating Costs** | |
| Milling/Maintenance | $15.00 |
| Processing | $20.00 |
| Tailings & Environmental | $2.10 |
| **Total Mill Operating** | $37.10 |
| Plant | **$1.50** |
| Admin Cost | **$1.50** |
| | |
| **Total Operating Costs** | **$90.10** |

## CAPITAL COST SUMMARY

| CAPITAL COSTS | |
|---|---|
| **Mine Capital Cost** | |
| Development | $200,000 |
| Equipment | $350,000 |
| Mine Plant Equipment, Buildings, Engineering | $0 |
| **Total Mine Capital** | **$550,000** |
| | |
| **Mill and Site Capital Costs** | |
| Direct Costs | $17,000,000 |
| Site Preparation (Hydro, Road) | $350,000 |
| Engineering | $1,360,000 |
| Environmental | $2,650,000 |
| **Total Mill Capital Costs** | **$21,360,000** |
| | |
| **Plant Admin Capital** | **$250,000** |
| **Total Capital Mine/Mill** | **$22,160,000** |

# St. STEPHEN NICKEL PROJECT
# (150,000 TPY) Value Added

| | | Yr 1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Yr 10 | End |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pay Factors (%) | % Ni | 100.00% | 100.00% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| | % Co | 100.00% | 100.00% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| | % Cu | 100.00% | 100.00% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| | | | | | | | | | | | | |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |
| Payable Metal Production (Dry Tons) | Ni | 993 | 993 | 993 | 993 | 993 | - | - | - | - | - | - |
| | Co | 114 | 114 | 114 | 114 | 114 | - | - | - | - | - | - |
| | Cu | 571 | 571 | 571 | 571 | 571 | - | - | - | - | - | - |
| | | | | | | | | | | | | |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |
| Metal Prices | Ni ($US/lb) | $5.25 | $5.25 | $5.25 | $5.25 | $5.25 | $5.25 | $5.25 | $5.25 | $5.25 | $5.25 | $5.25 |
| | Co ($US/lb) | $30.00 | $30.00 | $30.00 | $30.00 | $30.00 | $30.00 | $30.00 | $30.00 | $30.00 | $30.00 | $30.00 |
| | Cu ($US/lb) | $1.10 | $1.10 | $1.10 | $1.10 | $1.10 | $1.10 | $1.10 | $1.10 | $1.10 | $1.10 | $1.10 |
| | | Note: Value Added product at 1.5 times nickel price and 2 times cobalt metal price | | | | | | | | | | |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |
| Revenue ($US Mil) | Ni | $10.428 | $10.428 | $10.428 | $10.428 | $10.428 | - | - | - | - | - | - |
| | Co | $6.820 | $6.820 | $6.820 | $6.820 | $6.820 | - | - | - | - | - | - |
| | Cu | $1.256 | $1.256 | $1.256 | $1.256 | $1.256 | - | - | - | - | - | - |
| | | | | | | | | | | | | |
| | | - | - | - | - | - | - | - | - | - | - | - |
| | | - | - | - | - | - | - | - | - | - | - | - |
| Total | | $18.504 | $18.504 | $18.504 | $18.504 | $18.504 | - | - | - | - | - | - |
| Total Annual $CDN | | $24.673 | $24.673 | $24.673 | $24.673 | $24.673 | - | - | - | - | - | - |
| CDN Exchange Rate | $0.75 | | | | | | | | | | | |

## Smelting, Refining and Transportation Costs

| Smelting, Refining and Transportation Costs<br>($CDN) | | | | |
|---|---|---|---|---|
| **Metal** | **Impurity** | **Penalty** | **Base** | **ransportatio** |
| **Nickel** | | | 0 | 55 |
| | Penalties | | | |
| | Grade | | | |
| | Arsenic | | | |
| **Total Zinc** | | | 0 | 55 |
| **Lead** | | | 0 | 0 |
| | Penalties | | | |
| | Grade | | | |
| | Arsenic | | | |
| **Total Lead** | | | 0 | 0 |
| **Copper** | | | 90 | 55 |
| | Penalties | | | |
| | Grade | | | |
| | Arsenic | | | |
| **Total Copper** | | | 90 | 55 |
| **Other** | | | | 0 |
| | Penalties | | | |
| | Grade | | | |
| | Arsenic | | | |
| **Total Other** | | | 0 | 0 |

# St. STEPHEN NICKEL PROJECT
# (150,000 TPY) Value Added

| Bank Loan | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Begin Loan | 0 | 9,370 | 7,321 | 5,088 | 2,653 | 0 | 0 | 0 | 0 | 0 | |
| Loan Increase (Decrease) | 11,249 | | | | | | | | | | 11,249 |
| Payment | 2,892 | 2,892 | 2,892 | 2,892 | 2,892 | 0 | 0 | 0 | 0 | 0 | 14,461 |
| Interest Capital Loan | 1,012 | 843 | 659 | 458 | 239 | 0 | 0 | 0 | 0 | 0 | 3,211 |
| Principle Payment | 1,880 | 2,049 | 2,233 | 2,434 | 2,653 | 0 | 0 | 0 | 0 | 0 | 11,249 |
| End Bank Loan | 9,370 | 7,321 | 5,088 | 2,653 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Cash Flow | 5,656 | 5,465 | 4,118 | 3,537 | 6,048 | 0 | 0 | 0 | 0 | 0 | |
| Cumulative Cashflow | 5,656 | 11,121 | 15,239 | 18,776 | 24,824 | 24,824 | 24,824 | 24,824 | 24,824 | 24,824 | |
| Interest Operating Loan | (509) | (1,001) | (1,371) | (1,690) | (2,234) | (2,234) | (2,234) | (2,234) | (2,234) | (2,234) | |

% Debt 60%

# St. STEPHEN NICKEL PROJECT
# (150,000 TPY) Value Added

12/10/97

## Statement of Sources & Uses of Funds

(Constant CDN $ (000's))

| YEAR | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SOURCES OF FUNDS** | | | | | | | | | | | |
| Equity | 16,874 | - | - | - | - | - | - | - | - | - | 16,874 |
| Bank Loans | 11,249 | - | - | - | - | - | - | - | - | - | 11,249 |
| Net Income | (712) | (843) | (1,171) | 5,971 | 5,096 | - | - | - | - | - | 8,341 |
| Depreciation & Salvage | 8,248 | 8,548 | 7,713 | 191 | - | - | - | - | - | - | 24,700 |
| **TOTAL SOURCES** | 35,659 | 7,705 | 6,542 | 6,162 | 5,096 | - | - | - | - | - | 61,164 |
| | | | | | | | | | | | |
| **USES OF FUNDS** | | | | | | | | | | | |
| **Direct Costs** | | | | | | | | | | | - |
| Production Development | 200 | | | | | | - | - | - | - | 200 |
| Mining Equipment | 350 | 21 | 21 | 21 | 21 | - | - | - | - | - | 434 |
| Construction | - | | | | | | | | | | - |
| Milling Equipment | 17,000 | 170 | 170 | 170 | 170 | - | - | - | - | - | 17,680 |
| Spares & Inventory | 868 | | | | | | | | | | 868 |
| **Indirect Costs** | | | | | | | | | | | |
| Exploration | - | - | - | - | - | - | - | - | - | - | - |
| Eng/Mgmt/Construct | 3,260 | - | - | - | - | - | - | - | - | - | 3,260 |
| Environmental | 2,650 | - | - | - | - | - | - | - | - | - | 2,650 |
| Working Capital | 3,796 | - | - | - | (3,796) | - | - | - | - | - | (3,796) |
| **TOTAL USES** | 28,123 | 191 | 191 | 191 | (3,605) | - | - | - | - | - | 21,296 |
| | | | | | | | | | | | |
| Generated Cash From Ops. | 7,536 | 7,705 | 6,542 | 6,162 | 5,096 | - | - | - | - | - | 33,041 |
| Bank Loans | 11,249 | - | - | - | - | - | - | - | - | - | 11,249 |
| Bank Loan Repayment | 1,880 | 2,049 | 2,233 | 2,434 | 2,653 | - | - | - | - | - | 11,249 |
| **NET CASHFLOW** | (11,218) | 5,465 | 4,118 | 3,537 | 6,048 | - | - | - | - | - | 11,745 |

| NET PRESENT VALUE | | | |
|---|---|---|---|
| Discount Factor | - | 10% | 15% |
| NPV After Taxes | 11,745 | 4,492 | 2,581 |
| ROE 26.1% | | | |

# Appendix F

## Incubator Shake Flask Trials - Test Results

# Table F1. Iron titrations for Incubator Trials

1% Solids

Total Iron (gpl) — Ferric Ion (gpl)

Temperature = 50 deg C

| Days | INC 1 | INC 1A | INC 2 | INC 2A | INC 3 | INC 3A | Series INC-50 | INC 1 | INC 1A | INC 2 | INC 2A | INC 3 | INC 3A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Date | | | | | | |
| 0 | | | | | | | 25-Apr-97 | | | | | | |
| 17 | 7.16 | 12.86 | 8.50 | 9.28 | 6.60 | 3.47 | 12-May-97 | 5.48 | 11.85 | 7.72 | 8.50 | 6.26 | 2.91 |

Temperature = 52 deg C

| Days | INC4 | INC4A | INC5 | INC5A | INC6 | INC6A | Series INC-52 | INC4 | INC4A | INC5 | INC5A | INC6 | INC6A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| 0 | | | | | | | 14-May-97 | | | | | | |
| 19 | 13.19 | 20.46 | 20.12 | 4.02 | 3.35 | 2.57 | 02-Jun-97 | 11.29 | 18.45 | 18.22 | 2.57 | 2.01 | 1.45 |

Temperature = 48 deg C

| Days | INC7 | INC8 | INC9 | INC10 | INC11 | INC12 | Series INC-48 | INC7 | INC8 | INC9 | INC10 | INC11 | INC12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| 0 | | | | | | | 04-Jun-97 | | | | | | |
| 6 | INC19 | 5.37 | *"5 days"* | | | | 10-Jun-97 | | 2.12 | | | | |
| 10 | INC20 | 6.93 | *"10 days"* | | | | 14-Jun-97 | | 4.47 | | | | |
| 14 | INC21 | 9.95 | *"15 days"* | | | | 18-Jun-97 | | 9.39 | | | | |
| 19 | 13.08 | 8.61 | 4.81 | 5.59 | 7.16 | 6.04 | 23-Jun-97 | 10.84 | 6.26 | 4.02 | 5.25 | 6.04 | 4.92 |

Temperature = 54 deg C; 5, 10, 15 days (pH=1.5)

| Days | INC13 | INC14 | INC15 | INC16 | INC17 | INC18 | Series INC-54 | INC13 | INC14 | INC15 | INC16 | INC17 | INC18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| 0 | | | | | | | 04-Jul-97 | | | | | | |
| 5 | A= | 13.42 | *"5 days"* | | | | 08-Jul-97 | A= | 10.62 | | | | |
| 10 | B= | 8.16 | *"10 days"* | | | | 11-Jul-97 | B= | 5.70 | | | | |
| 15 | C= | 5.93 | *"15 days"* | | | | 16-Jul-97 | C= | 4.36 | | | | |
| 19 | 7.94 | 10.73 | 19.90 | 5.48 | 4.02 | 3.35 | 23-Jul-97 | 6.82 | 9.06 | 18.22 | 4.02 | 2.68 | 2.12 |

Temperature = 58 deg C

| Days | INC20 | INC21 | INC22 | INC23 | INC24 | INC25 | Series INC-58 | INC20 | INC21 | INC22 | INC23 | INC24 | INC25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Date | | | | | | |
| 0 | | | | | | | 18-Aug-97 | | | | | | |
| 21 | 10.62 | 13.08 | 12.07 | 3.91 | 3.80 | 4.25 | 08-Sep-97 | 9.84 | 11.40 | 10.62 | 2.57 | 2.80 | 3.24 |

Table F2. Solids Assay on Incubator Trials

| % Solids | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| INC1 | | | | | | | | |
| 1% | 40.20% | 4.02 | 0.568% | 8.50% | 0.48 | 88.0% | Fe | 76.40% |
| 1% | 1.28% | 0.13 | 0.568% | 0.15% | 0.01 | 93.3% | Cu | 88.94% |
| 1% | 0.97% | 0.10 | 0.568% | 0.136% | 0.01 | 92.0% | Ni | 91.83% |
| 1% | 654 | 7 | 0.568% | 113 | 0.64 | 90.2% | Co | 89.90% |
| INC1A | | | | | | | | |
| 1% | 40.20% | 4.02 | 0.943% | 15.00% | 1.41 | 64.8% | Fe | |
| 1% | 1.28% | 0.13 | 0.943% | 0.21% | 0.02 | 84.5% | Cu | |
| 1% | 0.97% | 0.10 | 0.943% | 0.086% | 0.01 | 91.6% | Ni | |
| 1% | 654 | 7 | 0.943% | 72 | 0.68 | 89.6% | Co | |
| INC2 | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.529% | 19.10% | 2.92 | 27.4% | Fe | 37.72% |
| 1% | 1.28% | 0.13 | 1.529% | 0.16% | 0.02 | 80.9% | Cu | 85.79% |
| 1% | 0.97% | 0.10 | 1.529% | 0.059% | 0.01 | 90.7% | Ni | 90.67% |
| 1% | 654 | 7 | 1.529% | 46 | 0.70 | 89.2% | Co | 88.93% |
| INC2A | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.242% | 16.80% | 2.09 | 48.1% | Fe | |
| 1% | 1.28% | 0.13 | 1.242% | 0.10% | 0.01 | 90.7% | Cu | |
| 1% | 0.97% | 0.10 | 1.242% | 0.073% | 0.01 | 90.6% | Ni | |
| 1% | 654 | 7 | 1.242% | 60 | 0.75 | 88.6% | Co | |
| INC3 | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.213% | 19.50% | 2.37 | 41.2% | Fe | 33.70% |
| 1% | 1.28% | 0.13 | 1.213% | 0.17% | 0.02 | 83.9% | Cu | 83.93% |
| 1% | 0.97% | 0.10 | 1.213% | 0.079% | 0.01 | 90.1% | Ni | 87.18% |
| 1% | 654 | 7 | 1.213% | 65 | 0.79 | 87.9% | Co | 84.56% |
| INC3A | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.865% | 15.90% | 2.97 | 26.2% | Fe | |
| 1% | 1.28% | 0.13 | 1.865% | 0.11% | 0.02 | 84.0% | Cu | |
| 1% | 0.97% | 0.10 | 1.865% | 0.082% | 0.02 | 84.3% | Ni | |
| 1% | 654 | 7 | 1.865% | 66 | 1.23 | 81.2% | Co | |

Table F3. Solids Assay on Incubator Trials

| % Solids | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| INC4 | | | | | | | | |
| 1% | 40.20% | 4.02 | 2.250% | 23.10% | 5.20 | -29.3% | Fe | -16.28% |
| 1% | 1.28% | 0.13 | 2.250% | 0.41% | 0.09 | 27.9% | Cu | 38.96% |
| 1% | 0.97% | 0.10 | 2.250% | 0.042% | 0.01 | 90.2% | Ni | 91.71% |
| 1% | 654 | 7 | 2.250% | 38 | 0.86 | 86.9% | Co | 88.87% |
| INC4A | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.940% | 21.40% | 4.15 | -3.3% | Fe | |
| 1% | 1.28% | 0.13 | 1.940% | 0.33% | 0.06 | 50.0% | Cu | |
| 1% | 0.97% | 0.10 | 1.940% | 0.034% | 0.01 | 93.2% | Ni | |
| 1% | 654 | 7 | 1.940% | 31 | 0.60 | 90.8% | Co | |
| INC5 | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.970% | 22.90% | 4.51 | -12.2% | Fe | -36.66% |
| 1% | 1.28% | 0.13 | 1.970% | 0.33% | 0.07 | 49.2% | Cu | 55.90% |
| 1% | 0.97% | 0.10 | 1.970% | 0.035% | 0.01 | 92.8% | Ni | 91.78% |
| 1% | 654 | 7 | 1.970% | 31 | 0.61 | 90.7% | Co | 89.36% |
| INC5A | | | | | | | | |
| 1% | 40.20% | 4.02 | 2.520% | 25.70% | 6.48 | -61.1% | Fe | |
| 1% | 1.28% | 0.13 | 2.520% | 0.19% | 0.05 | 62.6% | Cu | |
| 1% | 0.97% | 0.10 | 2.520% | 0.036% | 0.01 | 90.8% | Ni | |
| 1% | 654 | 7 | 2.520% | 31 | 0.78 | 88.1% | Co | |
| INC6 | | | | | | | | |
| 1% | 40.20% | 4.02 | 3.000% | 24.20% | 7.26 | -80.6% | Fe | -74.20% |
| 1% | 1.28% | 0.13 | 3.000% | 0.11% | 0.03 | 74.2% | Cu | 72.23% |
| 1% | 0.97% | 0.10 | 3.000% | 0.037% | 0.01 | 88.6% | Ni | 88.94% |
| 1% | 654 | 7 | 3.000% | 33 | 0.99 | 84.9% | Co | 85.78% |
| INC6A | | | | | | | | |
| 1% | 40.20% | 4.02 | 2.720% | 24.80% | 6.75 | -67.8% | Fe | |
| 1% | 1.28% | 0.13 | 2.720% | 0.14% | 0.04 | 70.3% | Cu | |
| 1% | 0.97% | 0.10 | 2.720% | 0.038% | 0.01 | 89.3% | Ni | |
| 1% | 654 | 7 | 2.720% | 32 | 0.87 | 86.7% | Co | |

## Table F4. Solids Assay on Incubator Trials

| % Solids | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| INC7 | | | | | | | | |
| 1% | 40.20% | 4.02 | 0.640% | 14.30% | 0.92 | 77.2% | Fe | 64.17% |
| 1% | 1.28% | 0.13 | 0.640% | 1.01% | 0.06 | 49.5% | Cu | 54.03% |
| 1% | 0.97% | 0.10 | 0.640% | 0.190% | 0.01 | 87.5% | Ni | 89.44% |
| 1% | 654 | 7 | 0.640% | 134 | 0.86 | 86.9% | Co | 87.48% |
| INC8 | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.040% | 18.90% | 1.97 | 51.1% | Fe | |
| 1% | 1.28% | 0.13 | 1.040% | 0.51% | 0.05 | 58.6% | Cu | |
| 1% | 0.97% | 0.10 | 1.040% | 0.080% | 0.01 | 91.4% | Ni | |
| 1% | 654 | 7 | 1.040% | 75 | 0.78 | 88.1% | Co | |
| INC9 | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.160% | 25.80% | 2.99 | 25.6% | Fe | 33.69% |
| 1% | 1.28% | 0.13 | 1.160% | 0.21% | 0.02 | 81.0% | Cu | 72.36% |
| 1% | 0.97% | 0.10 | 1.160% | 0.031% | 0.00 | 96.3% | Ni | 97.21% |
| 1% | 654 | 7 | 1.160% | 29 | 0.34 | 94.9% | Co | 95.97% |
| INC10 | | | | | | | | |
| 1% | 40.20% | 4.02 | 0.910% | 25.70% | 2.34 | 41.8% | Fe | |
| 1% | 1.28% | 0.13 | 0.910% | 0.51% | 0.05 | 63.7% | Cu | |
| 1% | 0.97% | 0.10 | 0.910% | 0.020% | 0.00 | 98.1% | Ni | |
| 1% | 654 | 7 | 0.910% | 21 | 0.19 | 97.1% | Co | |
| INC11 | | | | | | | | |
| 1% | 40.20% | 4.02 | 0.830% | 25.40% | 2.11 | 47.6% | Fe | 34.60% |
| 1% | 1.28% | 0.13 | 0.830% | 0.11% | 0.01 | 92.9% | Cu | 88.07% |
| 1% | 0.97% | 0.10 | 0.830% | 0.033% | 0.00 | 97.2% | Ni | 97.09% |
| 1% | 654 | 7 | 0.830% | 31 | 0.26 | 96.1% | Co | 96.11% |
| INC12 | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.260% | 25.00% | 3.15 | 21.6% | Fe | |
| 1% | 1.28% | 0.13 | 1.260% | 0.17% | 0.02 | 83.3% | Cu | |
| 1% | 0.97% | 0.10 | 1.260% | 0.023% | 0.00 | 97.0% | Ni | |
| 1% | 654 | 7 | 1.260% | 20 | 0.25 | 96.1% | Co | |
| INC19 (Day 5) | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.130% | 21.30% | 2.41 | 40.1% | Fe | |
| 1% | 1.28% | 0.13 | 1.130% | 0.35% | 0.04 | 69.1% | Cu | |
| 1% | 0.97% | 0.10 | 1.130% | 0.230% | 0.03 | 73.2% | Ni | |
| 1% | 654 | 7 | 1.130% | 202 | 2.28 | 65.1% | Co | |
| INC20 (Day 10) | | | | | | | | |
| 1% | 40.20% | 4.02 | 0.978% | 20.20% | 1.98 | 50.9% | Fe | |
| 1% | 1.28% | 0.13 | 0.978% | 0.36% | 0.04 | 72.5% | Cu | |
| 1% | 0.97% | 0.10 | 0.978% | 0.180% | 0.02 | 81.9% | Ni | |
| 1% | 654 | 7 | 0.978% | 155 | 1.52 | 76.8% | Co | |
| INC21 (Day 15) | | | | | | | | |
| 1% | 40.20% | 4.02 | 1.460% | 26.60% | 3.88 | 3.4% | Fe | |
| 1% | 1.28% | 0.13 | 1.460% | 0.46% | 0.07 | 47.5% | Cu | |
| 1% | 0.97% | 0.10 | 1.460% | 0.039% | 0.01 | 94.1% | Ni | |
| 1% | 654 | 7 | 1.460% | 34 | 0.50 | 92.4% | Co | |

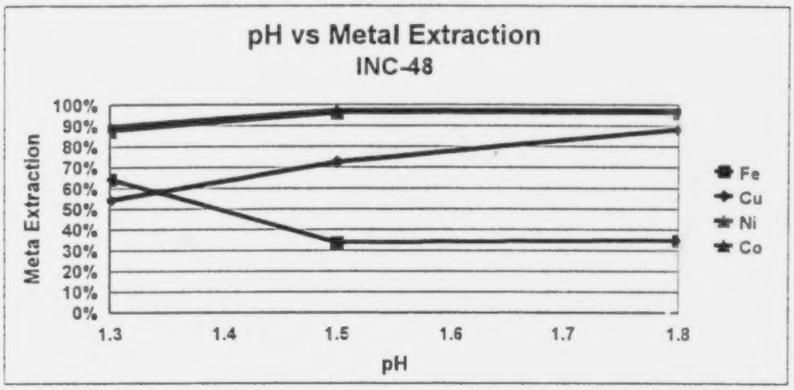
## Table F5. Solids Assay on Incubator Trials

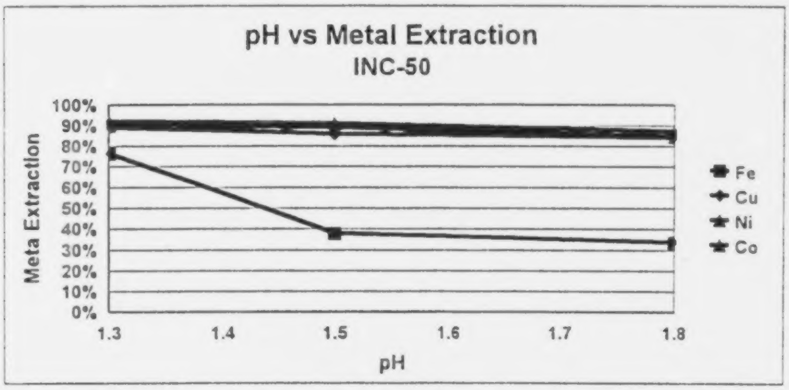
| % Solids | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| INC13 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.160% | 17.60% | 2.04 | 45.4% | Fe | 44.50% |
| 0.93% | 1.28% | 0.12 | 1.160% | 0.310% | 0.04 | 69.8% | Cu | 82.24% |
| 0.93% | 0.97% | 0.09 | 1.160% | 0.033% | 0.00 | 95.8% | Ni | 96.16% |
| 0.93% | 654 | 6 | 1.160% | 32 | 0.37 | 93.9% | Co | 94.40% |
| INC14 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.240% | 17.00% | 2.11 | 43.6% | Fe | |
| 0.93% | 1.28% | 0.12 | 1.240% | 0.051% | 0.01 | 94.7% | Cu | |
| 0.93% | 0.97% | 0.09 | 1.240% | 0.025% | 0.00 | 96.6% | Ni | |
| 0.93% | 654 | 6 | 1.240% | 25 | 0.31 | 94.9% | Co | |
| INC15 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.360% | 18.70% | 2.54 | 32.0% | Fe | 10.42% |
| 0.93% | 1.28% | 0.12 | 1.360% | 0.077% | 0.01 | 91.2% | Cu | 92.14% |
| 0.93% | 0.97% | 0.09 | 1.360% | 0.028% | 0.00 | 95.8% | Ni | 95.06% |
| 0.93% | 654 | 6 | 1.360% | 25 | 0.34 | 94.4% | Co | 93.66% |
| INC116 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.960% | 21.20% | 4.16 | -11.1% | Fe | |
| 0.93% | 1.28% | 0.12 | 1.960% | 0.042% | 0.01 | 93.1% | Cu | |
| 0.93% | 0.97% | 0.09 | 1.960% | 0.026% | 0.01 | 94.4% | Ni | |
| 0.93% | 654 | 6 | 1.960% | 22 | 0.43 | 92.9% | Co | |
| INC17 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 2.010% | 22.20% | 4.46 | -19.4% | Fe | -25.29% |
| 0.93% | 1.28% | 0.12 | 2.010% | 0.063% | 0.01 | 89.4% | Cu | 89.04% |
| 0.93% | 0.97% | 0.09 | 2.010% | 0.028% | 0.01 | 93.8% | Ni | 93.83% |
| 0.93% | 654 | 6 | 2.010% | 24 | 0.48 | 92.1% | Co | 92.42% |
| INC18 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 2.200% | 22.30% | 4.91 | -31.2% | Fe | |
| 0.93% | 1.28% | 0.12 | 2.200% | 0.061% | 0.01 | 88.7% | Cu | |
| 0.93% | 0.97% | 0.09 | 2.200% | 0.025% | 0.01 | 93.9% | Ni | |
| 0.93% | 654 | 6 | 2.200% | 20 | 0.44 | 92.8% | Co | |
| INC-A (Day 5) | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 0.856% | 18.30% | 1.57 | 58.1% | Fe | |
| 0.93% | 1.28% | 0.12 | 0.856% | 0.460% | 0.04 | 66.9% | Cu | |
| 0.93% | 0.97% | 0.09 | 0.856% | 0.270% | 0.02 | 74.4% | Ni | |
| 0.93% | 654 | 6 | 0.856% | 207 | 1.77 | 70.9% | Co | |
| INC-B(Day 10) | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.010% | 18.70% | 1.89 | 49.5% | Fe | |
| 0.93% | 1.28% | 0.12 | 1.010% | 0.200% | 0.02 | 83.0% | Cu | |
| 0.93% | 0.97% | 0.09 | 1.010% | 0.130% | 0.01 | 85.4% | Ni | |
| 0.93% | 654 | 6 | 1.010% | 102 | 1.03 | 83.1% | Co | |
| INC-C (Day 15) | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.420% | 20.20% | 2.87 | 23.3% | Fe | |
| 0.93% | 1.28% | 0.12 | 1.420% | 0.043% | 0.01 | 94.9% | Cu | |
| 0.93% | 0.97% | 0.09 | 1.420% | 0.048% | 0.01 | 92.4% | Ni | |
| 0.93% | 654 | 6 | 1.420% | 46 | 0.65 | 89.3% | Co | |

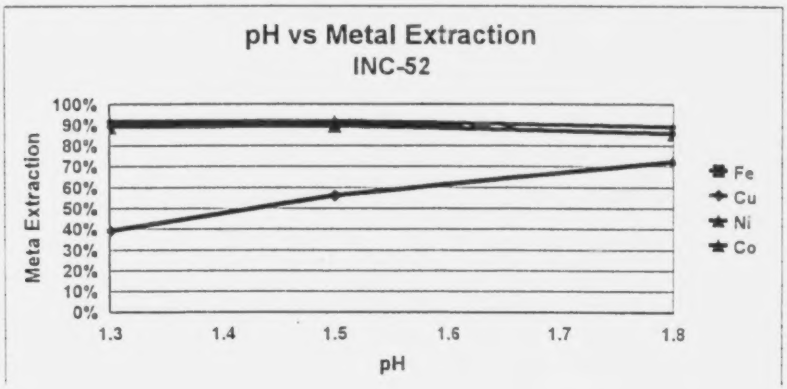
## Table F6. Solids Assay on Incubator Trials

| % Solids<br>INC20 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 0.93% | 40.20% | 3.74 | 0.429% | 4.30% | 0.18 | 95.1% | Fe | 90.68% |
| 0.93% | 1.28% | 0.12 | 0.429% | 0.601% | 0.03 | 78.3% | Cu | 82.61% |
| 0.93% | 0.97% | 0.09 | 0.429% | 0.062% | 0.00 | 97.1% | Ni | 97.24% |
| 0.93% | 654 | 6 | 0.429% | 76 | 0.33 | 94.6% | Co | 94.48% |
| INC21 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 0.617% | 8.30% | 0.51 | 86.3% | Fe | |
| 0.93% | 1.28% | 0.12 | 0.617% | 0.253% | 0.02 | 86.9% | Cu | |
| 0.93% | 0.97% | 0.09 | 0.617% | 0.038% | 0.00 | 97.4% | Ni | |
| 0.93% | 654 | 6 | 0.617% | 56 | 0.35 | 94.3% | Co | |
| INC22 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 0.951% | 15.90% | 1.51 | 59.6% | Fe | 46.73% |
| 0.93% | 1.28% | 0.12 | 0.951% | 0.094% | 0.01 | 92.5% | Cu | 95.23% |
| 0.93% | 0.97% | 0.09 | 0.951% | 0.022% | 0.00 | 97.7% | Ni | 97.72% |
| 0.93% | 654 | 6 | 0.951% | 24 | 0.23 | 96.2% | Co | 96.04% |
| INC23 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.267% | 19.50% | 2.47 | 33.9% | Fe | |
| 0.93% | 1.28% | 0.12 | 1.267% | 0.019% | 0.00 | 97.9% | Cu | |
| 0.93% | 0.97% | 0.09 | 1.267% | 0.016% | 0.00 | 97.8% | Ni | |
| 0.93% | 654 | 6 | 1.267% | 20 | 0.25 | 95.8% | Co | |
| INC24 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.740% | 22.70% | 3.95 | -5.6% | Fe | 4.22% |
| 0.93% | 1.28% | 0.12 | 1.740% | 0.067% | 0.01 | 90.2% | Cu | 92.35% |
| 0.93% | 0.97% | 0.09 | 1.740% | 0.026% | 0.00 | 95.0% | Ni | 95.83% |
| 0.93% | 654 | 6 | 1.740% | 26 | 0.45 | 92.6% | Co | 93.85% |
| INC25 | | | | | | | | |
| 0.93% | 40.20% | 3.74 | 1.480% | 21.70% | 3.21 | 14.1% | Fe | |
| 0.93% | 1.28% | 0.12 | 1.480% | 0.044% | 0.01 | 94.5% | Cu | |
| 0.93% | 0.97% | 0.09 | 1.480% | 0.020% | 0.00 | 96.7% | Ni | |
| 0.93% | 654 | 6 | 1.480% | 20 | 0.30 | 95.1% | Co | |

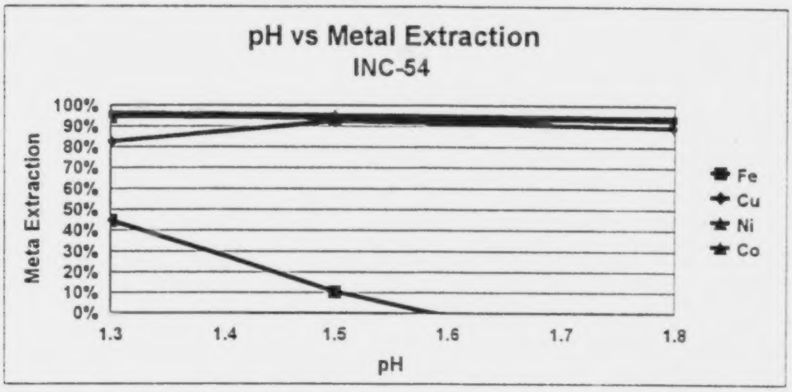
# Figure F1

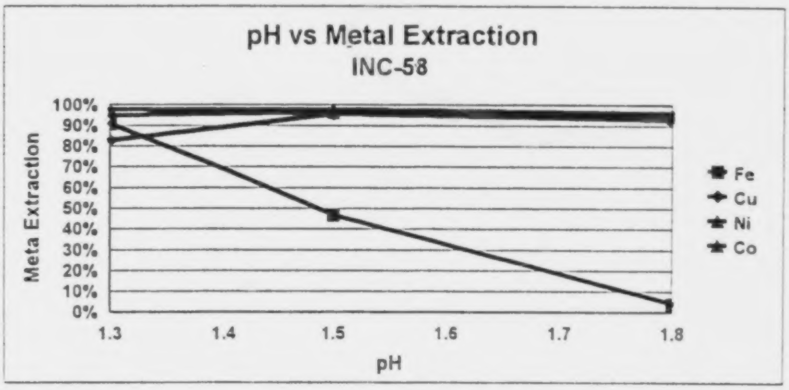

pH vs Metal Extraction
INC-48
Meta Extraction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co

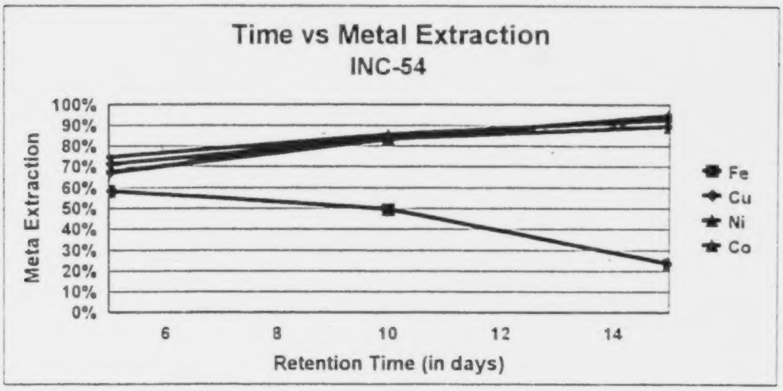

pH vs Metal Extraction
INC-50
Meta Extraction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co


pH vs Metal Extraction
INC-52
Meta Extraction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co

# Figure F2


pH vs Metal Extraction
INC-54
Meta Extraction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co


pH vs Metal Extraction
INC-58
Meta Extraction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co


Time vs Metal Extraction
INC-54
Meta Extraction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
6
8
10
12
14
Retention Time (in days)
Fe
Cu
Ni
Co

# Appendix G

## Stirred Flask Trials - Test Results

Table G1. Stirred Flask Tests (NCSF) - Test Conditions

| | Stirred Flask Numbers | | | | | |
|---|---|---|---|---|---|---|
| **Series 1** | **NCSF1** | **NCSF2** | **NCSF3** | **NCSF4** | **NCSF5** | **NCSF6** |
| Temperature (deg C) | 48-50 | 48-50 | 48-50 | 48-50 | 48-50 | 48-50 |
| pH | 1.2 - 1.5 | 1.2 - 1.5 | 1.2 - 1.5 | 1.2 - 1.5 | 1.2 - 1.5 | 1.2 - 1.5 |
| Total Iron (gpl) | 9 | 9 | 12.9 | 12.9 | 3.9 | 3.9 |
| Solids Loading | 10% | 10% | 10% | 10% | 10% | 10% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | 10K | 10K | 10K | 10K | 10K( no Fe) | 10K( no Fe) |
| Inoculum | None | None | Z3-OF | Z3-OF | Z3-OF | Z3-OF |

| **Series 2** | **NCSF7** | **NCSF8** | **NCSF9** | **NCSF10** | **NCSF11** | **NCSF12** |
|---|---|---|---|---|---|---|
| Temperature (deg C) | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 |
| pH | 1.20 | 1.20 | 1.50 | 1.50 | 1.80 | 1.80 |
| Total Iron (gpl) | 2-5 | 2-5 | 2-5 | 2-5 | 2-5 | 2-5 |
| Solids Loading | 15% | 15% | 15% | 15% | 15% | 15% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | NCSF-OF | NCSF-OF | NCSF-OF | NCSF-OF | NCSF-OF | NCSF-OF |

| **Series 3** | **NCSF13** | **NCSF14** | **NCSF15** | **NCSF16** | **NCSF17** | **NCSF18** |
|---|---|---|---|---|---|---|
| Temperature (deg C) | 46-48 | 46-48 | 46-48 | 46-48 | 46-48 | 46-48 |
| pH | 1.20 | 1.20 | 1.50 | 1.50 | 1.80 | 1.80 |
| Total Iron (gpl) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) |
| Solids Loading | 15% | 15% | 15% | 15% | 15% | 15% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF |

| **Series 4** | **NCSF19** | **NCSF20** | **NCSF21** | **NCSF22** | **NCSF23** | **NCSF24** |
|---|---|---|---|---|---|---|
| Temperature (deg C) | 46 | 46 | 46 | 46 | 46 | 46 |
| pH | 1.20 | 1.20 | 1.50 | 1.50 | 1.80 | 1.80 |
| Total Iron (gpl) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) |
| Solids Loading | 15% | 15% | 15% | 15% | 15% | 15% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF |

| **Series 5** | **NCSF25** | **NCSF26** | **NCSF27** | **NCS28** | **NCSF29** | **NCSF30** |
|---|---|---|---|---|---|---|
| Temperature (deg C) | 43 | 43 | 43 | 43 | 43 | 43 |
| pH | 1.20 | 1.20 | 1.50 | 1.50 | 1.80 | 1.80 |
| Total Iron (gpl) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) |
| Solids Loading | 15% | 15% | 15% | 15% | 15% | 15% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF |

Notes:
1. NCSF #1 had to be re-started due to H2S gassing
2. Tests all in duplicate
3. Tests to run 20-30 days
4. AMW - acid mine water at Mt. Pleasant Mines
5. "10K" represents a standard NPK nutrient mix with 10 gpl Iron added; "K": no Fe added
6. NCT-OF = Decant Solution from Culture Tank; Counts = 3.3M (24-Apr-97)
7. Series 3. NCT30 Culture(27-Apr-97, 17.89 gpl Fe(T) & 9.28 gpl Fe3+)

Table G2 . Stirred Flask (NCSF) Test Conditions

| | Test ID Numbers | | | | | |
|---|---|---|---|---|---|---|
| **Series 6** | NCSF31 | NCSF32 | NCSF33 | NCSF34 | NCSF35 | NCSF36 |
| Temperature (deg C) | 48 | 48 | 48 | 48 | 48 | 48 |
| pH | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Total Iron (gpl) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) |
| Solids Loading | 10% | 10% | 15% | 15% | 20% | 20% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF |

| **Series 7** | NCSF37 | NCSF38 | NCSF39 | NCSF40 | NCSF41 | NCSF42 |
|---|---|---|---|---|---|---|
| Temperature (deg C) | 48 | 48 | 48 | 48 | 48 | 48 |
| pH | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Total Iron (gpl) | 5 | 5 | 10 | 10 | 15 | 15 |
| Solids Loading | 15% | 15% | 15% | 15% | 15% | 15% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF |

| **Series 8** | NCSF43 | NCSF44 | NCSF45 | NCSF46 | NCSF47 | NCSF48 |
|---|---|---|---|---|---|---|
| Temperature (deg C) | 55 | 55 | 55 | 55 | 55 | 55 |
| pH | 1.20 | 1.20 | 1.50 | 1.50 | 1.80 | 1.80 |
| Total Iron (gpl) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) |
| Solids Loading | 15% | 15% | 15% | 15% | 15% | 15% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF |

| **Series 9** | NCSF49 | NCSF50 | NCSF51 | NCSF52 | NCSF53 | NCSF54 |
|---|---|---|---|---|---|---|
| Temperature (deg C) | 50 | 50 | 50 | 50 | 50 | 50 |
| pH | 1.20 | 1.20 | 1.50 | 1.50 | 1.80 | 1.80 |
| Total Iron (gpl) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) | 1.8(NCT30) |
| Solids Loading | 15% | 15% | 15% | 15% | 15% | 15% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) | Ore(80% -40u) |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF | NCT-OF |

| **Series 10** | NCSF60 | NCSF61 | NCSF62 | NCSF63 | NCSF64 | NCSF65 |
|---|---|---|---|---|---|---|
| Temperature (deg C) | 55 | 55 | 55 | 55 | 55 | 55 |
| pH | 1.20 | 1.20 | 1.50 | 1.50 | 1.80 | 1.80 |
| Total Iron (gpl) | 1.8(N3 O/F) | 1.8(N3 O/F) | 1.8(N3 O/F) | 1.8(N3 O/F) | 1.8(N3 O/F) | 1.8(N3 O/F) |
| Solids Loading | 15% | 15% | 15% | 15% | 15% | 15% |
| Volume | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW | 1.8 L AMW |
| Feed | Core | Core | Core | Core | Core | Core |
| Nutrient | "K" | "K" | "K" | "K" | "K" | "K" |
| Inoculum | N3-OF | N3-OF | N3-OF | N3-OF | N3-OF | N3-OF |

**Notes:**
1. "10K" represents a standard NPK nutrient mix with 10 gpl Iron added; "K"; no Fe added
2. Tests all in duplicate
3. Tests to run 20 days
4. AMW - acid mine water at Mt. Pleasant Mines
5. NCT-OF = Decant Solution from Culture Tank
6. Concentrate from TUNS Flotation Trials
7. N3-OF = Decant Solution from Pilot

**Table G3a. Iron titrations for NCT30A Culture**

**20% Solids**

**Total Iron (gpl)** **Ferric Ion (gpl)**

**Temperature = 48 deg C**

| Days | NCT | Comments | Series A | NCT | Ratio |
|---|---|---|---|---|---|
| | | | Date | | Fe3+/Fe |
| 0 | | 1 kg Feed Added | 18-Apr-97 | | |
| 4 | 13.86 | | 20-Apr-97 | 2.12 | 15% |
| 5 | 16.77 | 1 kg Feed Added | 21-Apr-97 | 4.25 | 25% |
| 7 | 19.01 | Count=3.3M/mL | 23-Apr-97 | 5.03 | 26% |
| 9 | 16.10 | | 25-Apr-97 | 5.93 | 37% |
| 11 | 17.89 | | 27-Apr-97 | 9.28 | 52% |
| 13 | | 1 kg Feed Added | 29-Apr-97 | | |
| 20 | 21.24 | 1 kg Feed Added | 06-May-97 | 5.48 | 26% |
| 23 | 22.92 | | 09-May-97 | 5.48 | 24% |
| 26 | 23.93 | | 12-May-97 | 9.84 | 41% |
| 27 | | 500g added | 13-May-97 | | |
| 29 | 35.66 | | 15-May-97 | 7.15 | 20% |
| 31 | 49.42 | | 17-May-97 | 24.49 | 50% |
| 33 | 48.86 | | 19-May-97 | 21.25 | 43% |
| 35 | 35.78 | | 21-May-97 | 16.33 | 46% |
| 38 | 34.21 | | 24-May-97 | 19.56 | 57% |
| 41 | 35.11 | | 27-May-97 | 22.14 | 63% |
| 47 | 35.89 | | 29-May-97 | 22.47 | 63% |
| | | Stopped | 02-Jun-97 | | |
| | | 4.5 kg = 15% | | | |

**Residue Assay: 24.4% Fe; 0.32% Cu; .146% Ni; 106 ppm Co**
**NCT30-05-06**

**Table G3b. Iron titrations for NCT30B Culture**

**20% Solids**

**Total Iron (gpl)** **Ferric Ion (gpl)**

**Temperature = 48 deg C**

| Days | NCT | Comments | Series B | NCT | Ratio |
|---|---|---|---|---|---|
| | | | Date | | Fe3+/Fe |
| 0 | 15.43 | 300g feed added | 06-Jun-97 | 10.40 | 10.40 |
| 3 | 27.06 | | 09-Jun-97 | 17.89 | 66% |
| 5 | 21.58 | | 11-Jun-97 | 13.08 | 61% |
| 10 | 19.68 | 300g feed added | 16-Jun-97 | 12.86 | 65% |
| 13 | 17.44 | | 19-Jun-97 | 7.98 | 46% |
| 17 | 15.65 | | 23-Jun-97 | 8.61 | 55% |
| 20 | 18.67 | 300g feed added | 26-Jun-97 | 7.49 | 40% |
| 25 | 20.12 | | 01-Jul-97 | 16.77 | 83% |
| | 0.00 | 300g feed added | 02-Jul-97 | | 0% |
| 28 | 21.58 | | 04-Jul-97 | 16.66 | 77% |
| 32 | 19.12 | 300g feed added | 07-Jul-97 | 16.88 | 88% |
| 35 | 22.58 | 300g feed added | 10-Jul-97 | 14.42 | 64% |
| 38 | 26.94 | 300g feed added | 14-Jul-97 | 16.32 | 61% |
| 42 | 25.94 | | 18-Jul-97 | 15.54 | 60% |
| 46 | 22.36 | | 22-Jul-97 | 16.55 | 74% |
| 50 | 0.00 | 600g feed added | 24-Jul-97 | | 0% |
| 54 | 24.04 | | 28-Jul-97 | 13.42 | 56% |
| 56 | 23.25 | 300g feed added | 30-Jul-97 | 14.87 | 64% |
| 64 | 23.03 | | 07-Aug-97 | 12.19 | 53% |
| 69 | 24.93 | | 12-Aug-97 | 11.07 | 44% |
| 76 | 27.39 | | 19-Aug-97 | 16.32 | 60% |
| 79 | 29.07 | | 22-Aug-97 | 16.55 | 57% |
| 82 | 28.29 | | 25-Aug-97 | 16.55 | 59% |
| 85 | 31.42 | | 28-Aug-97 | 27.84 | 89% |
| 91 | 39.35 | | 03-Sep-97 | 23.93 | 61% |
| | 0.00 | | | | 0% |
| | | | | | |

## Table G4. Iron titrations for NCSF's

NCSF's TOTAL IRON LOADINGS (gpl) NCSF's FERRIC ION LOADINGS (gpl)

Temperature = 47 deg C

| Days | NCSF 1 | NCSF 2 | NCSF 3 | NCSF 4 | NCSF 5 | NCSF 6 | Series 1 | NCSF 1 | NCSF 2 | NCSF 3 | NCSF 4 | NCSF 5 | NCSF 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Date | | | | | | |
| 0 | 9.00 | 9.00 | 12.90 | 12.90 | 3.90 | 3.90 | 01-Apr-97 | | | | | | |
| 2 | 22.47 | 34.77 | 27.06 | 24.82 | 15.76 | 17.44 | 03-Apr-97 | 1.23 | 3.13 | 4.92 | 2.24 | 1.12 | 2.35 |
| 4 | 27.28 | 34.21 | 35.33 | 28.84 | 27.28 | 26.16 | 07-Apr-97 | 1.34 | 9.84 | 8.83 | 2.01 | 4.92 | 5.81 |
| 8 | 32.09 | 33.20 | 32.53 | 31.86 | 30.19 | 26.27 | 11-Apr-97 | 7.16 | 16.32 | 12.97 | 5.81 | 9.61 | 8.61 |
| 12 | 40.70 | 38.91 | 35.55 | 33.54 | 28.84 | 28.62 | 15-Apr-97 | 13.64 | 24.82 | 18.00 | 7.27 | 9.17 | 10.96 |
| 14 | 34.83 | 28.40 | 31.08 | 31.42 | 25.71 | 19.57 | 18-Apr-97 | 10.96 | 18.34 | 19.01 | 3.80 | 9.84 | 8.39 |
| Fe(adj.) | 25.83 | 19.40 | 18.18 | 18.52 | 21.81 | 15.67 | | | | | | | |
| Assay | 26.80 | 24.10 | 40.20 | 26.00 | 21.00 | 16.90 | | | | | | | |

Temperature = 40 deg C

| Days | NCSF 7 | NCSF 8 | NCSF 9 | NCSF 10 | NCSF 11 | NCSF 12 | Series 2 | NCSF 7 | NCSF 8 | NCSF 9 | NCSF 10 | NCSF 11 | NCSF 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.79 | 1.79 | 1.79 | 1.79 | 1.79 | 1.79 | 28-Apr-97 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| 4 | 21.69 | 21.91 | 21.80 | 18.56 | 13.53 | 9.06 | 02-May-97 | 1.9 | 0.22 | 0.45 | 4.58 | 1.34 | 0.22 |
| 8 | 36.00 | 29.96 | 31.42 | 35.33 | 22.81 | 16.32 | 06-May-97 | 4.14 | 1.01 | 1.57 | 10.06 | 2.57 | 1.57 |
| 11 | 53.33 | 43.71 | 54.89 | 37.34 | 37.68 | 31.08 | 09-May-97 | 9.61 | 6.71 | 2.12 | 0.78 | 7.27 | 4.58 |
| 16 | 62.94 | 59.25 | 50.53 | 44.50 | 44.16 | 36.45 | 14-May-97 | 17.77 | 16.21 | 20.34 | 5.93 | 13.30 | 9.28 |
| 18 | 54.78 | 47.96 | 43.94 | 44.38 | 36.45 | 45.73 | 16-May-97 | 9.84 | 4.81 | 11.18 | 3.58 | 3.13 | 3.47 |
| Fe(adj.) | 52.99 | 46.17 | 42.15 | 42.59 | 34.66 | 43.94 | | | | | | | |
| Assay | 49.10 | 51.20 | 43.70 | 50.30 | 37.00 | 47.90 | | | | | | | |

Temperature = 47 deg C

| Days | NCSF 13 | NCSF 14 | NCSF 15 | NCSF 16 | NCSF 17 | NCSF 18 | Series 3 | NCSF 13 | NCSF 14 | NCSF 15 | NCSF 16 | NCSF 17 | NCSF 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.79 | 1.79 | 1.79 | 1.79 | 1.79 | 1.79 | 28-Apr-97 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 | 0.93 |
| 4 | 14.31 | 15.09 | 10.73 | 11.96 | 4.92 | 5.37 | 02-May-97 | 2.01 | 1.57 | 1.01 | 1.57 | -0.11 | -0.22 |
| 8 | 29.29 | 20.91 | 26.27 | 16.10 | 21.24 | 10.62 | 06-May-97 | 5.70 | 6.82 | 3.13 | 7.38 | 3.02 | 1.90 |
| 11 | 27.70 | 19.80 | 31.10 | 13.20 | 22.80 | 12.20 | 09-May-97 | 2.91 | 2.68 | 8.27 | 1.90 | 0.89 | 2.01 |
| 16 | 46.40 | 23.14 | 27.28 | 19.34 | 30.19 | 14.42 | 14-May-97 | 20.24 | 2.57 | 4.14 | 4.02 | 6.94 | 2.23 |
| 18 | 31.53 | 28.96 | 24.37 | 33.76 | 36.34 | 14.20 | 16-May-97 | 10.17 | 4.58 | 4.58 | 17.66 | 5.93 | 2.12 |
| Fe(adj.) | 29.74 | 27.17 | 22.58 | 31.97 | 34.55 | 12.41 | | | | | | | |
| Assay | 31.30 | 30.10 | 23.30 | 19.60 | 33.90 | 14.30 | | | | | | | |

Temperature = 46 deg C

| Days | NCSF 19 | NCSF 20 | NCSF 21 | NCSF 22 | NCSF 23 | NCSF 24 | Series 4 | NCSF 19 | NCSF 20 | NCSF 21 | NCSF 22 | NCSF 23 | NCSF 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 21-May-97 | 2.02 | 2.02 | 2.02 | 2.02 | 2.02 | 2.02 |
| 12 | 18.34 | 11.07 | 11.40 | 10.62 | 12.97 | 9.28 | 02-Jun-97 | 7.04 | 4.58 | 5.48 | 5.93 | 6.26 | 4.92 |
| 15 | 22.81 | 18.56 | 15.76 | 14.42 | 10.17 | 16.66 | 05-Jun-97 | 13.86 | 11.63 | 8.50 | 7.04 | 2.57 | 6.82 |
| 19 | 26.16 | 24.71 | 18.78 | 19.12 | 9.28 | 15.43 | 09-Jun-97 | 18.67 | 19.01 | 14.09 | 13.86 | 4.25 | 2.80 |
| Fe(adj.) | 22.84 | 21.39 | 15.46 | 15.80 | 5.96 | 12.11 | | | | | | | |
| Assay | | | | | | | | | | | | | |

Temperature = 43 deg C

| Days | NCSF 25 | NCSF 26 | NCSF 27 | NCSF 28 | NCSF 29 | NCSF 30 | Series 5 | NCSF 25 | NCSF 26 | NCSF 27 | NCSF 28 | NCSF 29 | NCSF 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 3.59 | 3.59 | 3.59 | 3.59 | 3.59 | 3.59 | 27-May-97 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 | 2.25 |
| 6 | 10.96 | 8.05 | 5.70 | 15.76 | 12.30 | 6.60 | 02-Jun-97 | 5.37 | 2.68 | 3.47 | 6.37 | 4.58 | 4.02 |
| 9 | 22.47 | 15.99 | 15.43 | 18.34 | 17.89 | 18.34 | 05-Jun-97 | 3.13 | 3.35 | 5.14 | 3.58 | 0.89 | 7.38 |
| 15 | 42.82 | 35.33 | 21.24 | 25.04 | 26.61 | 22.25 | 11-Jun-97 | 26.05 | 10.62 | 4.81 | 10.84 | 5.59 | 6.48 |
| 18 | 32.20 | 34.99 | 19.68 | 21.91 | 23.48 | 18.78 | 14-Jun-97 | 19.68 | 13.75 | 5.59 | 12.30 | 6.15 | 5.93 |
| Fe(adj.) | 28.61 | 31.40 | 16.09 | 18.32 | 19.89 | 15.19 | | | | | | | |
| Assay | | | | | | | | | | | | | |

## Table G5. Iron titrations for NCSF's

**NCSF's TOTAL IRON LOADINGS (gpl)**

**Temperature = 47 deg C; pH=1.5; Solids Loading 10, 15, 20%**

| Days | NCSF 31 | NCSF 32 | NCSF 33 | NCSF 34 | NCSF 35 | NCSF 36 | Series 6 | NCSF 31 | NCSF 32 | NCSF 33 | NCSF 34 | NCSF 35 | NCSF 36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.74 | 1.74 | 1.74 | 1.74 | 1.74 | 1.74 | 19-Jun-97 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 |
| 3 | 7.60 | 6.15 | 6.82 | 7.04 | 20.79 | 10.96 | 22-Jun-97 | 1.34 | 0.89 | 1.23 | 1.45 | 0.67 | 0.78 |
| 8 | 11.85 | 10.40 | 9.39 | 9.50 | 25.38 | 16.21 | 27-Jun-97 | 3.80 | 3.58 | 1.68 | 1.68 | 9.39 | 1.79 |
| 12 | 20.12 | 15.20 | 17.89 | 18.00 | 34.77 | 21.47 | 01-Jul-97 | 5.14 | 2.68 | 3.35 | 3.47 | 5.70 | 3.58 |
| 15 | 30.19 | 25.16 | 29.07 | 29.18 | 35.66 | 24.15 | 04-Jul-97 | 15.99 | 12.75 | 11.52 | 10.73 | 11.63 | 6.04 |
| 19 | 31.08 | 23.81 | 21.47 | 24.04 | 32.09 | 23.70 | 08-Jul-97 | 20.35 | 14.20 | 5.03 | 7.38 | 15.09 | 7.49 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Temperature = 48 deg C; pH=1.5; 15% Solids; Fe-5,10,15 gpl**

| Days | NCSF 37 | NCSF 38 | NCSF 39 | NCSF 40 | NCSF 41 | NCSF 42 | Series 7 | NCSF 37 | NCSF 38 | NCSF 39 | NCSF 40 | NCSF 41 | NCSF 42 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 6.74 | 6.74 | 11.74 | 11.74 | 16.74 | 16.74 | 19-Jun-97 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 | 0.74 |
| 3 | 11.29 | 10.40 | 14.53 | 15.32 | 25.04 | 21.24 | 22-Jun-97 | 1.12 | 0.89 | 1.01 | 2.12 | 6.71 | 1.34 |
| 8 | 18.67 | 17.11 | 20.35 | 22.92 | 29.85 | 24.60 | 27-Jun-97 | 3.69 | 3.47 | 4.47 | 5.59 | 9.61 | 4.14 |
| 12 | 24.82 | 27.73 | 27.39 | 35.22 | 33.65 | 28.62 | 01-Jul-97 | 4.14 | 5.81 | 6.48 | 13.97 | 7.60 | 6.60 |
| 15 | 31.86 | 33.32 | 33.54 | 39.13 | 35.89 | 30.63 | 04-Jul-97 | 12.52 | 14.42 | 13.08 | 18.78 | 11.63 | 8.27 |
| 19 | 24.26 | 40.14 | 40.47 | 38.57 | 32.20 | 27.17 | 08-Jul-97 | 5.59 | 21.24 | 21.47 | 17.44 | 12.86 | 8.39 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Temperature = 55 deg C; pH=1.2, 1.5, 1.8; 15% Solids; K Nutrient**

| Days | NCSF 43 | NCSF 44 | NCSF 45 | NCSF 46 | NCSF 47 | NCSF 48 | Series 8 | NCSF 43 | NCSF 44 | NCSF 45 | NCSF 46 | NCSF 47 | NCSF 48 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 |  |  |  |  |  |  | 24-Jul-97 |  |  |  |  |  |  |
| 8 | 15.09 | 15.99 | 13.64 | 10.73 | 8.16 | 11.18- | 01-Aug-97 | 12.52 | 12.30 | 10.40 | 6.60 | 5.70 | 6.71 |
| 12 | 20.01 | 18.34 | 16.21 | 13.86 | 10.84 | 14.53 | 05-Aug-97 | 16.55 | 11.85 | 10.84 | 8.83 | 6.37 | 9.39 |
| 19 | 18.89 | 20.24 | 16.99 | 19.57 | 18.56 | 12.86 | 12-Aug-97 | 15.09 | 15.20 | 12.75 | 15.43 | 14.87 | 8.94 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Temperature = 50 deg C; pH=1.2, 1.5, 1.8; 15% Solids; K Nutrient**

| Days | NCSF 49 | NCSF 50 | NCSF 51 | NCSF 52 | NCSF 53 | NCSF 54 | Series 9 | NCSF 49 | NCSF 50 | NCSF 51 | NCSF 52 | NCSF 53 | NCSF 54 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 |  |  |  |  |  |  | 05-Aug-97 |  |  |  |  |  |  |
| 7 | 20.79 | 17.78 | 14.65 | 12.07 | 9.50 | 7.94 | 12-Aug-97 | 7.83 | 6.48 | 6.48 | 2.68 | 3.47 | 2.46 |
| 10 | 26.16 | 21.58 | 18.78 | 17.22 | 12.52 | 11.07 | 15-Aug-97 | 11.18 | 7.49 | 7.83 | 5.81 | 4.47 | 4.02 |
| 15 | 32.09 | 23.25 | 22.92 | 22.92 | 15.65 | 13.19 | 20-Aug-97 | 21.47 | 10.17 | 11.96 | 10.40 | 8.27 | 6.26 |
| 20 | 33.54 | 23.14 | 24.93 | 22.36 | 19.68 | 13.97 | 25-Aug-97 | 28.06 | 14.76 | 13.97 | 9.84 | 12.30 | 6.37 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Temperature = 55 deg C; pH=1.2, 1.5, 1.8; 15% Solids; K Nutrient; N3 O/F**

| Days | NCSF 60 | NCSF 61 | NCSF 62 | NCSF 63 | NCSF 64 | NCSF 65 | Series 10 | NCSF 60 | NCSF 61 | NCSF 62 | NCSF 63 | NCSF 64 | NCSF 65 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 5.39 | 5.39 | 5.39 | 5.39 | 5.39 | 5.39 | 27-Nov-97 | 2.625 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 |
| 7 | 16.88 | 16.88 | 13.53 | 17.89 | 16.77 | 15.20 | 03-Dec-97 | 4.25 | 6.26 | 5.48 | 10.96 | 10.40 | 8.72 |
| 13 | 19.34 | 18.78 | 15.54 | 19.23 | 17.44 | 17.78 | 09-Dec-97 | 5.37 | 7.16 | 5.81 | 10.84 | 9.50 | 8.94 |
| 16 | 48.07 | 47.40 | 31.30 | 31.30 | 18.89 | 23.70 | 12-Dec-97 | 18.67 | 19.23 | 13.97 | 14.42 | 7.10 | 11.30 |
| 21 | 50.87 | 55.12 | 41.70 | 36.45 | 24.71 | 22.92 | 17-Dec-97 | 17.44 | 18.89 | 19.79 | 15.65 | 12.07 | 9.28 |
| 22 | 47.29 | 47.85 | 40.36 | 41.59 | 24.82 | 36.00 | 18-Dec-97 | 14.76 | 10.29 | 18.00 | 18.45 | 10.29 | 22.92 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

## Table G6. Solids Assay on NCSF (Series 1 - 14 Days)

| % Solids<br>NCSF2 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal |
|---|---|---|---|---|---|---|---|
| 10% | 40.20% | 40.20 | 8.44% | 19.00% | 16.04 | 60.1% | Fe |
| 10% | 1.28% | 1.28 | 8.44% | 0.51% | 0.43 | 66.4% | Cu |
| 10% | 0.97% | 0.97 | 8.44% | 0.21% | 0.18 | 81.7% | Ni |
| 10% | 650 | 65 | 8.44% | 151 | 12.74 | 80.4% | Co |
| | | | | | | | |
| NCSF4 | | | | | | | |
| 10% | 40.20% | 40.20 | 6.96% | 22.30% | 15.52 | 61.4% | Fe |
| 10% | 1.28% | 1.28 | 6.96% | 0.85% | 0.59 | 53.8% | Cu |
| 10% | 0.97% | 0.97 | 6.96% | 0.68% | 0.47 | 51.2% | Ni |
| 10% | 650 | 65 | 6.96% | 440 | 30.62 | 52.9% | Co |
| | | | | | | | |
| NCSF6 | | | | | | | |
| 10% | 40.20% | 40.20 | 6.55% | 19.00% | 12.45 | 69.0% | Fe |
| 10% | 1.28% | 1.28 | 6.55% | 0.58% | 0.38 | 70.3% | Cu |
| 10% | 0.97% | 0.97 | 6.55% | 0.26% | 0.17 | 82.4% | Ni |
| 10% | 650 | 65 | 6.55% | 205 | 13.43 | 79.3% | Co |
| | | | | | | | |

## Table G7. Solids Assay on NCSF (Series 2 - 18 Days)

| % Solids<br>NCSF7 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 15% | 40.20% | 60.30 | 8.78% | 12.70% | 11.15 | 81.5% | Fe | |
| 15% | 1.28% | 1.92 | 8.78% | 1.13% | 0.99 | 48.3% | Cu | |
| 15% | 0.97% | 1.46 | 8.78% | 0.87% | 0.76 | 47.5% | Ni | |
| 15% | 650 | 98 | 8.78% | 861 | 75.60 | 22.5% | Co | |
| | | | | | | | | |
| NCSF8 | | | | | | | | |
| 15% | 40.20% | 60.30 | 9.17% | 13.50% | 12.38 | 79.5% | Fe | 80.49% |
| 15% | 1.28% | 1.92 | 9.17% | 1.28% | 1.17 | 38.9% | Cu | 43.60% |
| 15% | 0.97% | 1.46 | 9.17% | 0.82% | 0.75 | 48.3% | Ni | 47.91% |
| 15% | 650 | 98 | 9.17% | 866 | 79.41 | 18.6% | Co | 20.51% |
| | | | | | | | | |
| NCSF9 | | | | | | | | |
| 15% | 40.20% | 60.30 | 12.53% | 16.70% | 20.93 | 65.3% | Fe | |
| 15% | 1.28% | 1.92 | 12.53% | 0.59% | 0.74 | 61.5% | Cu | |
| 15% | 0.97% | 1.46 | 12.53% | 0.39% | 0.49 | 66.4% | Ni | |
| 15% | 650 | 98 | 12.53% | 325 | 40.72 | 58.2% | Co | |
| | | | | | | | | |
| NCSF10 | | | | | | | | |
| 15% | 40.20% | 60.30 | 11.43% | 16.00% | 18.29 | 69.7% | Fe | 67.48% |
| 15% | 1.28% | 1.92 | 11.43% | 1.26% | 1.44 | 25.0% | Cu | 43.24% |
| 15% | 0.97% | 1.46 | 11.43% | 0.74% | 0.85 | 41.9% | Ni | 54.14% |
| 15% | 650 | 98 | 11.43% | 729 | 83.32 | 14.5% | Co | 36.39% |
| | | | | | | | | |
| NCSF11 | | | | | | | | |
| 15% | 40.20% | 60.30 | 12.19% | 21.50% | 26.21 | 56.5% | Fe | |
| 15% | 1.28% | 1.92 | 12.19% | 1.21% | 1.47 | 23.2% | Cu | |
| 15% | 0.97% | 1.46 | 12.19% | 0.71% | 0.87 | 40.5% | Ni | |
| 15% | 650 | 98 | 12.19% | 695 | 84.72 | 13.1% | Co | |
| | | | | | | | | |
| NCSF12 | | | | | | | | |
| 15% | 40.20% | 60.30 | 11.10% | 17.80% | 19.76 | 67.2% | Fe | 61.89% |
| 15% | 1.28% | 1.92 | 11.10% | 1.69% | 1.88 | 2.3% | Cu | 12.74% |
| 15% | 0.97% | 1.46 | 11.10% | 1.04% | 1.15 | 20.7% | Ni | 30.59% |
| 15% | 650 | 98 | 11.10% | 844 | 93.68 | 3.9% | Co | 8.51% |
| | | | | | | | | |

Table G8. Solids Assay on NCSF (Series 3 - 18 Days)

| % Solids<br>NCSF13 | Grade | Weight f Metal | % Solids in residue | Residue Assay | Weight f Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 15% | 40.20% | 60.30 | 12.37% | 26.70% | 33.03 | 45.2% | Fe | |
| 15% | 1.28% | 1.92 | 12.37% | 0.40% | 0.49 | 74.2% | Cu | |
| 15% | 0.97% | 1.46 | 12.37% | 0.34% | 0.42 | 71.1% | Ni | |
| 15% | 650 | 98 | 12.37% | 295 | 36.49 | 62.6% | Co | |
| | | | | | | | | |
| NCSF14 | | | | | | | | |
| 15% | 40.20% | 60.30 | 13.32% | 25.40% | 33.83 | 43.9% | Fe | 44.56% |
| 15% | 1.28% | 1.92 | 13.32% | 0.67% | 0.89 | 53.5% | Cu | 63.87% |
| 15% | 0.97% | 1.46 | 13.32% | 0.42% | 0.56 | 61.6% | Ni | 66.32% |
| 15% | 650 | 98 | 13.32% | 277 | 36.90 | 62.2% | Co | 62.37% |
| | | | | | | | | |
| NCSF15 | | | | | | | | |
| 15% | 40.20% | 60.30 | 12.87% | 27.60% | 35.52 | 41.1% | Fe | |
| 15% | 1.28% | 1.92 | 12.87% | 0.43% | 0.55 | 71.2% | Cu | |
| 15% | 0.97% | 1.46 | 12.87% | 0.33% | 0.42 | 70.8% | Ni | |
| 15% | 650 | 98 | 12.87% | 265 | 34.11 | 65.0% | Co | |
| | | | | | | | | |
| NCSF16 | | | | | | | | |
| 15% | 40.20% | 60.30 | 13.75% | 29.30% | 40.29 | 33.2% | Fe | 37.14% |
| 15% | 1.28% | 1.92 | 13.75% | 0.61% | 0.84 | 56.3% | Cu | 63.75% |
| 15% | 0.97% | 1.46 | 13.75% | 0.33% | 0.45 | 68.8% | Ni | 69.81% |
| 15% | 650 | 98 | 13.75% | 239 | 32.36 | 66.3% | Co | 65.56% |
| | | | | | | | | |
| NCSF17 | | | | | | | | |
| 15% | 40.20% | 60.30 | 12.04% | 22.90% | 27.57 | 54.3% | Fe | |
| 15% | 1.28% | 1.92 | 12.04% | 1.56% | 1.88 | 2.2% | Cu | |
| 15% | 0.97% | 1.46 | 12.04% | 0.86% | 1.04 | 28.8% | Ni | |
| 15% | 650 | 98 | 12.04% | 661 | 79.58 | 18.4% | Co | |
| | | | | | | | | |
| NCSF18 | | | | | | | | |
| 15% | 40.20% | 60.30 | 13.98% | 34.10% | 47.67 | 20.9% | Fe | 37.61% |
| 15% | 1.28% | 1.92 | 13.98% | 0.80% | 1.12 | 41.8% | Cu | 21.96% |
| 15% | 0.97% | 1.46 | 13.98% | 0.39% | 0.55 | 62.5% | Ni | 45.68% |
| 15% | 650 | 98 | 13.98% | 233 | 32.57 | 66.6% | Co | 42.48% |
| | | | | | | | | |

Table G9. Solids Assay on NCSF (Series 4 - 19 Days)

| % Solids<br>NCSF19 | Grade | Weight f Metal | % Solids in residue | Residue Assay | Weight f Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 15% | 40.20% | 60.30 | 16.46% | 25.40% | 41.81 | 30.7% | Fe | |
| 15% | 1.28% | 1.92 | 16.46% | 0.35% | 0.58 | 70.0% | Cu | |
| 15% | 0.97% | 1.46 | 16.46% | 0.16% | 0.26 | 81.9% | Ni | |
| 15% | 650 | 98 | 16.46% | 127 | 20.90 | 78.6% | Co | |
| | | | | | | | | |
| NCSF20 | | | | | | | | |
| 15% | 40.20% | 60.30 | 16.59% | 27.70% | 45.95 | 23.8% | Fe | 27.23% |
| 15% | 1.28% | 1.92 | 16.59% | 0.23% | 0.38 | 80.1% | Cu | 75.06% |
| 15% | 0.97% | 1.46 | 16.59% | 0.17% | 0.28 | 80.6% | Ni | 81.26% |
| 15% | 650 | 98 | 16.59% | 135 | 22.40 | 77.0% | Co | 77.79% |
| | | | | | | | | |
| NCSF21 | | | | | | | | |
| 15% | 40.20% | 60.30 | 18.22% | 30.10% | 54.84 | 9.1% | Fe | |
| 15% | 1.28% | 1.92 | 18.22% | 0.25% | 0.46 | 76.3% | Cu | |
| 15% | 0.97% | 1.46 | 18.22% | 0.17% | 0.31 | 78.7% | Ni | |
| 15% | 650 | 98 | 18.22% | 129 | 23.50 | 75.9% | Co | |
| | | | | | | | | |
| NCSF22 | | | | | | | | |
| 15% | 40.20% | 60.30 | 18.20% | 31.40% | 57.15 | 5.2% | Fe | 7.14% |
| 15% | 1.28% | 1.92 | 18.20% | 0.23% | 0.42 | 78.2% | Cu | 77.24% |
| 15% | 0.97% | 1.46 | 18.20% | 0.15% | 0.27 | 81.2% | Ni | 79.97% |
| 15% | 650 | 98 | 18.20% | 121 | 22.02 | 77.4% | Co | 76.65% |
| | | | | | | | | |
| NCSF23 | | | | | | | | |
| 15% | 40.20% | 60.30 | 16.61% | 34.10% | 56.64 | 6.1% | Fe | |
| 15% | 1.28% | 1.92 | 16.61% | 0.18% | 0.30 | 84.4% | Cu | |
| 15% | 0.97% | 1.46 | 16.61% | 0.16% | 0.27 | 81.7% | Ni | |
| 15% | 650 | 98 | 16.61% | 128 | 21.26 | 78.2% | Co | |
| | | | | | | | | |
| NCSF24 | | | | | | | | |
| 15% | 40.20% | 60.30 | 16.39% | 27.60% | 45.24 | 25.0% | Fe | 15.53% |
| 15% | 1.28% | 1.92 | 16.39% | 0.70% | 1.15 | 40.2% | Cu | 62.34% |
| 15% | 0.97% | 1.46 | 16.39% | 0.32% | 0.52 | 64.0% | Ni | 72.84% |
| 15% | 650 | 98 | 16.39% | 226 | 37.04 | 62.0% | Co | 70.10% |
| | | | | | | | | |

Table G10. Solids Assay on NCSF (Series 5 - 18 Days)

| % Solids NCSF25 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | etal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 15% | 40.20% | 60.30 | 12.82% | 22.10% | 28.33 | 53.0% | Fe | |
| 15% | 1.28% | 1.92 | 12.82% | 0.34% | 0.44 | 77.3% | Cu | |
| 15% | 0.97% | 1.46 | 12.82% | 0.22% | 0.28 | 80.6% | Ni | |
| 15% | 650 | 98 | 12.82% | 184 | 23.59 | 75.8% | Co | |
| | | | | | | | | |
| NCSF26 | | | | | | | | |
| 15% | 40.20% | 60.30 | 11.03% | 22.40% | 24.71 | 59.0% | Fe | 56.02% |
| 15% | 1.28% | 1.92 | 11.03% | 0.79% | 0.87 | 54.6% | Cu | 65.96% |
| 15% | 0.97% | 1.46 | 11.03% | 0.30% | 0.33 | 77.3% | Ni | 78.94% |
| 15% | 650 | 98 | 11.03% | 260 | 28.68 | 70.6% | Co | 73.20% |
| | | | | | | | | |
| NCSF27 | | | | | | | | |
| 15% | 40.20% | 60.30 | 13.20% | 26.20% | 34.58 | 42.6% | Fe | |
| 15% | 1.28% | 1.92 | 13.20% | 0.71% | 0.94 | 51.2% | Cu | |
| 15% | 0.97% | 1.46 | 13.20% | 0.30% | 0.40 | 72.8% | Ni | |
| 15% | 650 | 98 | 13.20% | 228 | 30.10 | 69.1% | Co | |
| | | | | | | | | |
| NCSF28 | | | | | | | | |
| 15% | 40.20% | 60.30 | 14.97% | 27.10% | 40.57 | 32.7% | Fe | 37.68% |
| 15% | 1.28% | 1.92 | 14.97% | 0.35% | 0.52 | 72.7% | Cu | 61.95% |
| 15% | 0.97% | 1.46 | 14.97% | 0.21% | 0.31 | 78.4% | Ni | 75.59% |
| 15% | 650 | 98 | 14.97% | 172 | 25.75 | 73.6% | Co | 71.36% |
| | | | | | | | | |
| NCSF29 | | | | | | | | |
| 15% | 40.20% | 60.30 | 13.92% | 27.30% | 38.00 | 37.0% | Fe | |
| 15% | 1.28% | 1.92 | 13.92% | 0.36% | 0.50 | 73.9% | Cu | |
| 15% | 0.97% | 1.46 | 13.92% | 0.33% | 0.46 | 68.4% | Ni | |
| 15% | 650 | 98 | 13.92% | 269 | 37.44 | 61.6% | Co | |
| | | | | | | | | |
| NCSF30 | | | | | | | | |
| 15% | 40.20% | 60.30 | 16.97% | 25.00% | 42.43 | 29.6% | Fe | 33.31% |
| 15% | 1.28% | 1.92 | 16.97% | 0.51% | 0.87 | 54.9% | Cu | 64.41% |
| 15% | 0.97% | 1.46 | 16.97% | 0.21% | 0.36 | 75.5% | Ni | 71.97% |
| 15% | 650 | 98 | 16.97% | 169 | 28.68 | 70.6% | Co | 66.09% |
| | | | | | | | | |

Table G11. Solids Assay on NCSF (Series 6 - 19 Days)

| % Solids NCSF31 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | etal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 10% | 40.20% | 40.20 | 10.26% | 19.30% | 19.80 | 50.7% | Fe | |
| 10% | 1.28% | 1.28 | 10.26% | 0.33% | 0.34 | 73.5% | Cu | |
| 10% | 0.97% | 0.97 | 10.26% | 0.12% | 0.12 | 87.3% | Ni | |
| 10% | 650 | 65 | 10.26% | 87 | 8.93 | 86.3% | Co | |
| | | | | | | | | |
| NCSF32 | | | | | | | | |
| 10% | 40.20% | 40.20 | 9.72% | 22.80% | 22.16 | 44.9% | Fe | 47.81% |
| 10% | 1.28% | 1.28 | 9.72% | 0.32% | 0.31 | 75.7% | Cu | 74.62% |
| 10% | 0.97% | 0.97 | 9.72% | 0.13% | 0.13 | 87.0% | Ni | 87.14% |
| 10% | 650 | 65 | 9.72% | 91 | 8.85 | 86.4% | Co | 86.33% |
| | | | | | | | | |
| NCSF33 | | | | | | | | |
| 15% | 40.20% | 60.30 | 14.02% | 23.10% | 32.39 | 46.3% | Fe | |
| 15% | 1.28% | 1.92 | 14.02% | 0.29% | 0.41 | 78.8% | Cu | |
| 15% | 0.97% | 1.46 | 14.02% | 0.24% | 0.34 | 76.9% | Ni | |
| 15% | 650 | 98 | 14.02% | 179 | 25.10 | 74.3% | Co | |
| | | | | | | | | |
| NCSF34 | | | | | | | | |
| 15% | 40.20% | 60.30 | 14.07% | 22.90% | 32.22 | 46.6% | Fe | 46.43% |
| 15% | 1.28% | 1.92 | 14.07% | 0.35% | 0.49 | 74.4% | Cu | 76.59% |
| 15% | 0.97% | 1.46 | 14.07% | 0.29% | 0.41 | 72.0% | Ni | 74.42% |
| 15% | 650 | 98 | 14.07% | 185 | 26.03 | 73.3% | Co | 73.78% |
| | | | | | | | | |
| NCSF35 | | | | | | | | |
| 20% | 40.20% | 80.40 | 22.56% | 25.90% | 58.43 | 27.3% | Fe | |
| 20% | 1.28% | 2.56 | 22.56% | 0.26% | 0.59 | 77.1% | Cu | |
| 20% | 0.97% | 1.94 | 22.56% | 0.26% | 0.59 | 69.8% | Ni | |
| 20% | 650 | 130 | 22.56% | 164 | 37.00 | 71.5% | Co | |
| | | | | | | | | |
| NCSF36 | | | | | | | | |
| 20% | 40.20% | 80.40 | 21.68% | 27.40% | 59.40 | 26.1% | Fe | 26.72% |
| 20% | 1.28% | 2.56 | 21.68% | 0.32% | 0.69 | 72.9% | Cu | 74.99% |
| 20% | 0.97% | 1.94 | 21.68% | 0.29% | 0.63 | 67.6% | Ni | 68.68% |
| 20% | 650 | 130 | 21.68% | 190 | 41.19 | 68.3% | Co | 69.93% |
| | | | | | | | | |

## Table G12. Solids Assay on NCSF (Series 7 - 19 Days)

| % Solids NCSF37 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 15% | 40.20% | 60.30 | 17.66% | 26.70% | 47.15 | 21.8% | Fe | |
| 15% | 1.28% | 1.92 | 17.66% | 0.26% | 0.46 | 76.1% | Cu | |
| 15% | 0.97% | 1.46 | 17.66% | 0.21% | 0.37 | 74.5% | Ni | |
| 15% | 650 | 98 | 17.66% | 153 | 27.02 | 72.3% | Co | |
| NCSF38 | | | | | | | | |
| 15% | 40.20% | 60.30 | 15.98% | 18.50% | 29.56 | 51.0% | Fe | 36.39% |
| 15% | 1.28% | 1.92 | 15.98% | 0.50% | 0.80 | 58.4% | Cu | 67.24% |
| 15% | 0.97% | 1.46 | 15.98% | 0.25% | 0.40 | 72.5% | Ni | 73.53% |
| 15% | 650 | 98 | 15.98% | 164 | 26.21 | 73.1% | Co | 72.70% |
| NCSF39 | | | | | | | | |
| 15% | 40.20% | 60.30 | 17.36% | 24.30% | 42.18 | 30.0% | Fe | |
| 15% | 1.28% | 1.92 | 17.36% | 0.40% | 0.69 | 63.8% | Cu | |
| 15% | 0.97% | 1.46 | 17.36% | 0.21% | 0.36 | 74.9% | Ni | |
| 15% | 650 | 98 | 17.36% | 139 | 24.13 | 75.3% | Co | |
| NCSF40 | | | | | | | | |
| 15% | 40.20% | 60.30 | 20.50% | 23.40% | 47.97 | 20.4% | Fe | 25.24% |
| 15% | 1.28% | 1.92 | 20.50% | 0.37% | 0.76 | 60.5% | Cu | 62.16% |
| 15% | 0.97% | 1.46 | 20.50% | 0.21% | 0.43 | 70.4% | Ni | 72.68% |
| 15% | 650 | 98 | 20.50% | 139 | 28.50 | 70.8% | Co | 73.01% |
| NCSF41 | | | | | | | | |
| 15% | 40.20% | 60.30 | 16.32% | 27.00% | 44.06 | 26.9% | Fe | |
| 15% | 1.28% | 1.92 | 16.32% | 0.30% | 0.49 | 74.5% | Cu | |
| 15% | 0.97% | 1.46 | 16.32% | 0.17% | 0.28 | 80.9% | Ni | |
| 15% | 650 | 98 | 16.32% | 114 | 18.60 | 80.9% | Co | |
| NCSF42 | | | | | | | | |
| 15% | 40.20% | 60.30 | 18.24% | 23.10% | 42.13 | 30.1% | Fe | 28.53% |
| 15% | 1.28% | 1.92 | 18.24% | 0.30% | 0.55 | 71.5% | Cu | 73.00% |
| 15% | 0.97% | 1.46 | 18.24% | 0.20% | 0.36 | 74.9% | Ni | 77.93% |
| 15% | [illegible]50 | 98 | 18.24% | 130 | 23.71 | 75.7% | Co | 78.30% |

## Table G13. Solids Assay on NCSF (Series 8 - 19 Days)

| % Solids NCSF43 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 15% | 40.20% | 60.30 | 9.45% | 29.60% | 27.97 | 53.6% | Fe | |
| 15% | 1.28% | 1.92 | 9.45% | 0.06% | 0.06 | 97.0% | Cu | |
| 15% | 0.97% | 1.46 | 9.45% | 0.09% | 0.08 | 94.3% | Ni | |
| 15% | 650 | 98 | 9.45% | 58 | 5.48 | 94.4% | Co | |
| NCSF44 | | | | | | | | |
| 15% | 40.20% | 60.30 | 9.44% | 27.10% | 25.58 | 57.6% | Fe | 55.59% |
| 15% | 1.28% | 1.92 | 9.44% | 0.08% | 0.08 | 95.9% | Cu | 96.46% |
| 15% | 0.97% | 1.46 | 9.44% | 0.08% | 0.07 | 94.9% | Ni | 94.54% |
| 15% | 650 | 98 | 9.44% | 67 | 6.32 | 93.5% | Co | 93.95% |
| NCSF45 | | | | | | | | |
| 15% | 40.20% | 60.30 | 10.15% | 29.10% | 29.54 | 51.0% | Fe | |
| 15% | 1.28% | 1.92 | 10.15% | 0.07% | 0.07 | 96.5% | Cu | |
| 15% | 0.97% | 1.46 | 10.15% | 0.08% | 0.08 | 94.4% | Ni | |
| 15% | 650 | 98 | 10.15% | 59 | 5.99 | 93.9% | Co | |
| NCSF46 | | | | | | | | |
| 15% | 40.20% | 60.30 | 10.51% | 30.60% | 32.16 | 46.7% | Fe | 48.34% |
| 15% | 1.28% | 1.92 | 10.51% | 0.07% | 0.07 | 96.1% | Cu | 96.29% |
| 15% | 0.97% | 1.46 | 10.51% | 0.09% | 0.09 | 93.7% | Ni | 94.07% |
| 15% | 650 | 98 | 10.51% | 64 | 6.73 | 93.1% | Co | 93.48% |
| NCSF47 | | | | | | | | |
| 15% | 40.20% | 60.30 | 10.59% | 29.90% | 31.66 | 47.5% | Fe | |
| 15% | 1.28% | 1.92 | 10.59% | 0.13% | 0.14 | 92.8% | Cu | |
| 15% | 0.97% | 1.46 | 10.59% | 0.12% | 0.13 | 91.3% | Ni | |
| 15% | 650 | 98 | 10.59% | 79 | 8.37 | 91.4% | Co | |
| NCSF48 | | | | | | | | |
| 15% | 40.20% | 60.30 | 11.28% | 31.30% | 35.31 | 41.4% | Fe | 44.47% |
| 15% | 1.28% | 1.92 | 11.28% | 0.25% | 0.28 | 85.3% | Cu | 89.07% |
| 15% | 0.97% | 1.46 | 11.28% | 0.30% | 0.34 | 76.7% | Ni | 84.00% |
| 15% | 650 | 98 | 11.28% | 70 | 7.90 | 91.9% | Co | 91.66% |

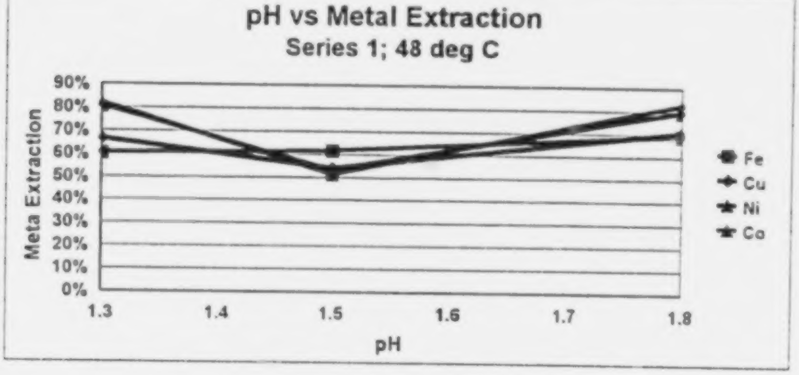
Table G14. Solids Assay on NCSF (Series 9 - 20 Days)

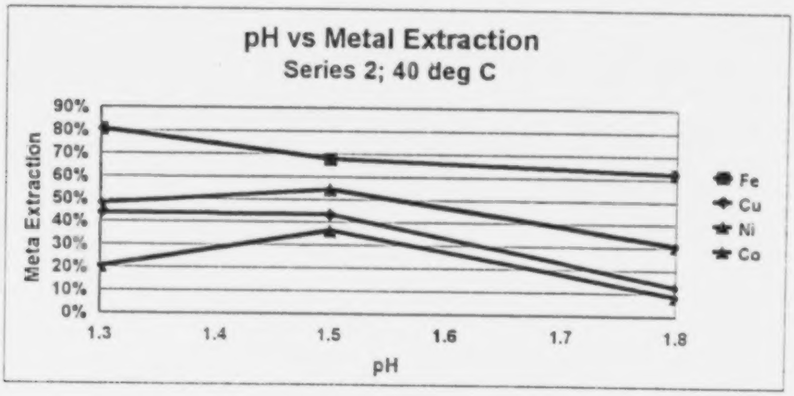
| % Solids NCSF49 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 15% | 40.20% | 60.30 | 9.28% | 23.00% | 21.34 | 64.6% | Fe | |
| 15% | 1.28% | 1.92 | 9.28% | 0.30% | 0.28 | 85.5% | Cu | |
| 15% | 0.97% | 1.46 | 9.28% | 0.11% | 0.10 | 93.0% | Ni | |
| 15% | 650 | 98 | 9.28% | 87 | 8.07 | 91.7% | Co | |
| | | | | | | | | |
| NCSF50 | | | | | | | | |
| 15% | 40.20% | 60.30 | 9.04% | 25.30% | 22.87 | 62.1% | Fe | 63.34% |
| 15% | 1.28% | 1.92 | 9.04% | 0.22% | 0.20 | 89.5% | Cu | 87.52% |
| 15% | 0.97% | 1.46 | 9.04% | 0.14% | 0.13 | 91.3% | Ni | 92.14% |
| 15% | 650 | 98 | 9.04% | 116 | 10.49 | 89.2% | Co | 90.48% |
| | | | | | | | | |
| NCSF51 | | | | | | | | |
| 15% | 40.20% | 60.30 | 9.79% | 26.80% | 26.24 | 56.5% | Fe | |
| 15% | 1.28% | 1.92 | 9.79% | 0.26% | 0.25 | 86.7% | Cu | |
| 15% | 0.97% | 1.46 | 9.79% | 0.23% | 0.23 | 84.5% | Ni | |
| 15% | 650 | 98 | 9.79% | 169 | 16.55 | 83.0% | Co | |
| | | | | | | | | |
| NCSF52 | | | | | | | | |
| 15% | 40.20% | 60.30 | 8.81% | 24.30% | 21.41 | 64.5% | Fe | 60.49% |
| 15% | 1.28% | 1.92 | 8.81% | 0.20% | 0.18 | 90.8% | Cu | 88.78% |
| 15% | 0.97% | 1.46 | 8.81% | 0.26% | 0.23 | 84.3% | Ni | 84.39% |
| 15% | 650 | 98 | 8.81% | 179 | 15.77 | 83.8% | Co | 83.43% |
| | | | | | | | | |
| NCSF53 | | | | | | | | |
| 15% | 40.20% | 60.30 | 10.28% | 30.10% | 30.94 | 48.7% | Fe | |
| 15% | 1.28% | 1.92 | 10.28% | 0.29% | 0.30 | 84.5% | Cu | |
| 15% | 0.97% | 1.46 | 10.28% | 0.23% | 0.24 | 83.7% | Ni | |
| 15% | 650 | 98 | 10.28% | 136 | 13.98 | 85.7% | Co | |
| | | | | | | | | |
| NCSF54 | | | | | | | | |
| 15% | 40.20% | 60.30 | 10.63% | 29.50% | 31.36 | 48.0% | Fe | 48.34% |
| 15% | 1.28% | 1.92 | 10.63% | 0.34% | 0.36 | 81.2% | Cu | 82.82% |
| 15% | 0.97% | 1.46 | 10.63% | 0.18% | 0.19 | 87.1% | Ni | 85.45% |
| 15% | 650 | 98 | 10.63% | 133 | 14.14 | 85.5% | Co | 85.58% |

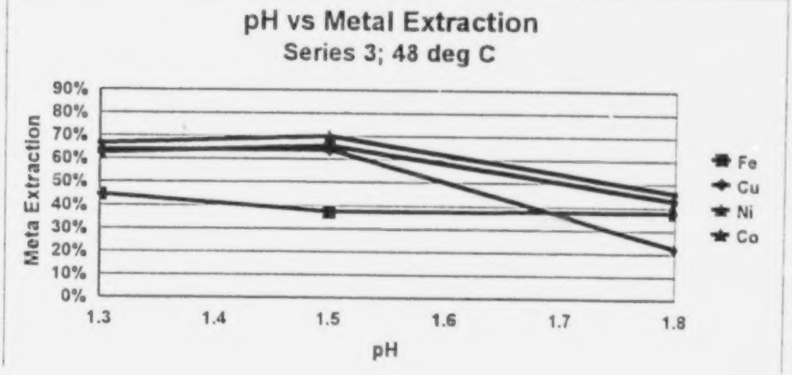
Table G15. Solids Assay on NCSF (Series 10 - 21 Days)

| % Solids NCSF60 | Grade | Weight of Metal | % Solids in residue | Residue Assay | Weight of Metal | % Metal Extraction | Metal | Average Extraction |
|---|---|---|---|---|---|---|---|---|
| 15% | 46.40% | 69.60 | 11.85% | 31.80% | 37.68 | 45.9% | Fe | |
| 15% | 0.71% | 1.07 | 11.85% | 0.61% | 0.72 | 32.1% | Cu | |
| 15% | 1.76% | 2.64 | 11.85% | 1.61% | 1.91 | 27.7% | Ni | |
| 15% | 1430 | 215 | 11.85% | 1510 | 178.94 | 16.6% | Co | |
| | | | | | | | | |
| NCSF61 | | | | | | | | |
| 15% | 46.40% | 69.60 | 12.23% | 28.40% | 34.73 | 50.1% | Fe | 47.98% |
| 15% | 0.71% | 1.07 | 12.23% | 0.45% | 0.55 | 48.3% | Cu | 40.23% |
| 15% | 1.76% | 2.64 | 12.23% | 1.41% | 1.72 | 34.7% | Ni | 31.21% |
| 15% | 1430 | 215 | 12.23% | 1290 | 157.77 | 26.4% | Co | 21.51% |
| | | | | | | | | |
| NCSF62 | | | | | | | | |
| 15% | 46.40% | 69.60 | 14.64% | 34.80% | 50.95 | 26.8% | Fe | |
| 15% | 0.71% | 1.07 | 14.64% | 0.60% | 0.88 | 17.5% | Cu | |
| 15% | 1.76% | 2.64 | 14.64% | 1.35% | 1.98 | 25.1% | Ni | |
| 15% | 1430 | 215 | 14.64% | 1200 | 175.68 | 18.1% | Co | |
| | | | | | | | | |
| NCSF63 | | | | | | | | |
| 15% | 46.40% | 69.60 | 13.91% | 35.70% | 49.66 | 28.7% | Fe | 27.73% |
| 15% | 0.71% | 1.07 | 13.91% | 0.40% | 0.56 | 47.8% | Cu | 32.64% |
| 15% | 1.76% | 2.64 | 13.91% | 1.21% | 1.68 | 36.2% | Ni | 30.69% |
| 15% | 1430 | 215 | 13.91% | 1160 | 161.36 | 24.8% | Co | 21.44% |
| | | | | | | | | |
| NCSF64 | | | | | | | | |
| 15% | 46.40% | 69.60 | 15.42% | 38.90% | 59.98 | 13.8% | Fe | |
| 15% | 0.71% | 1.07 | 15.42% | 0.54% | 0.83 | 21.8% | Cu | |
| 15% | 1.76% | 2.64 | 15.42% | 1.25% | 1.93 | 27.0% | Ni | |
| 15% | 1430 | 215 | 15.42% | 1160 | 178.87 | 16.6% | Co | |
| | | | | | | | | |
| NCSF65 | | | | | | | | |
| 15% | 46.40% | 69.60 | 15.97% | 37.40% | 59.73 | 14.2% | Fe | 14.00% |
| 15% | 0.71% | 1.07 | 15.97% | 0.43% | 0.69 | 35.5% | Cu | 28.67% |
| 15% | 1.76% | 2.64 | 15.97% | 0.91% | 1.45 | 45.0% | Ni | 35.97% |
| 15% | 1430 | 215 | 15.97% | 784 | 125.20 | 41.6% | Co | 29.12% |

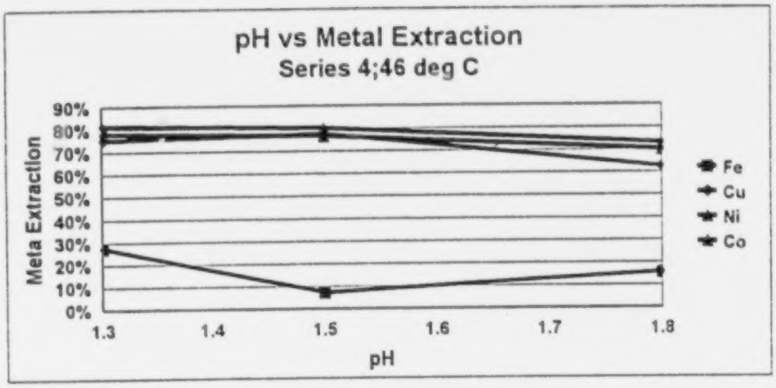
# Figure G1

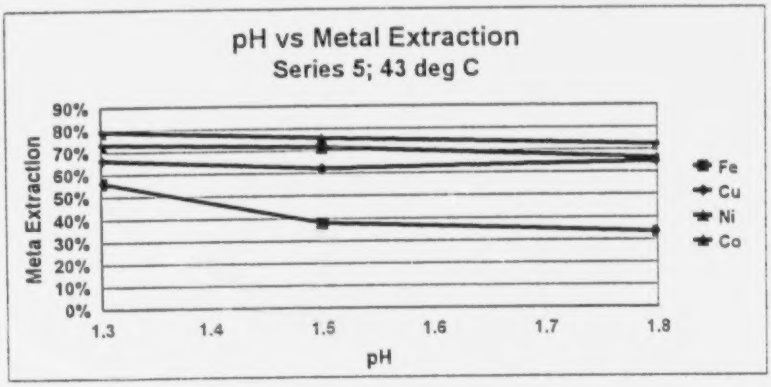

pH vs Metal Extraction
Series 1; 48 deg C
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Meta Extraction
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co

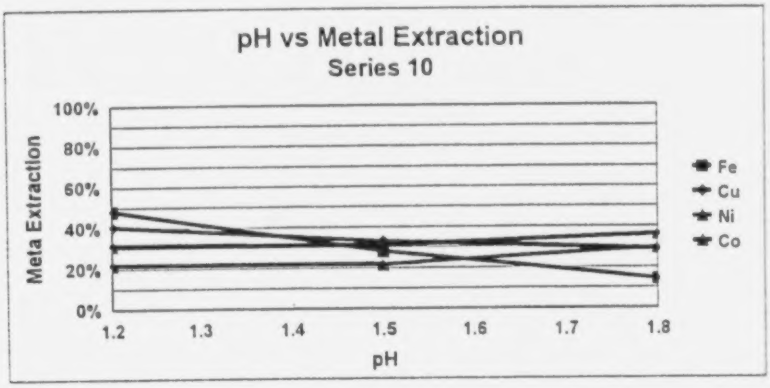

pH vs Metal Extraction
Series 2; 40 deg C
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Meta Extraction
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co


pH vs Metal Extraction
Series 3; 48 deg C
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Meta Extraction
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co

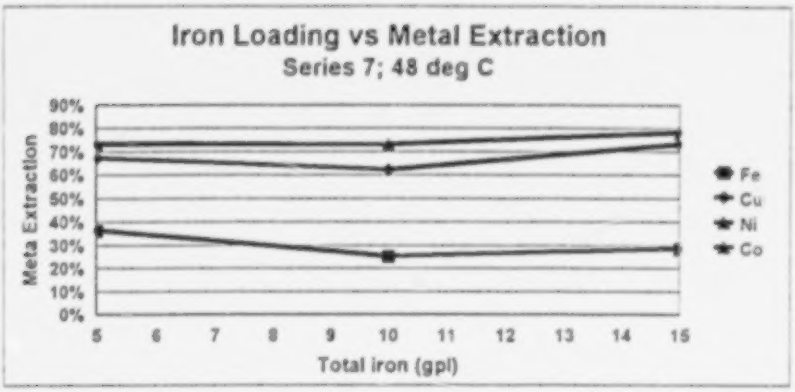
# Figure G2

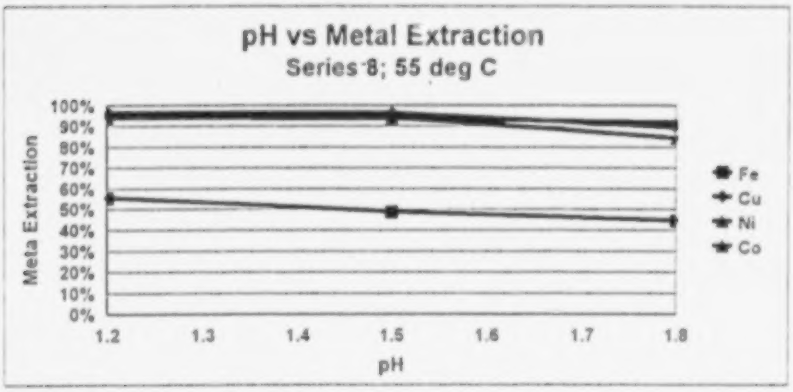

pH vs Metal Extraction
Series 4;46 deg C
Meta Extraction
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co

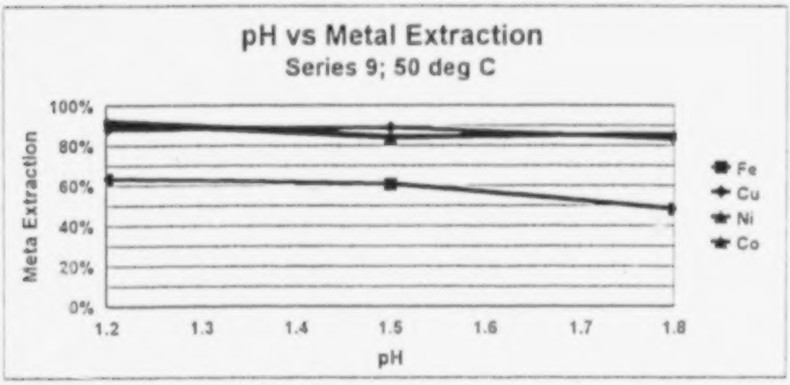

pH vs Metal Extraction
Series 5; 43 deg C
Meta Extraction
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co


pH vs Metal Extraction
Series 10
Meta Extraction
100%
80%
60%
40%
20%
0%
1.2
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co

# Figure G3


Iron Loading vs Metal Extraction
Series 7; 48 deg C
Meta Extraction
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
5
6
7
8
9
10
11
12
13
14
15
Total iron (gpl)
Fe
Cu
Ni
Co


pH vs Metal Extraction
Series 8; 55 deg C
Meta Extraction
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1.2
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co


pH vs Metal Extraction
Series 9; 50 deg C
Meta Extraction
100%
80%
60%
40%
20%
0%
1.2
1.3
1.4
1.5
1.6
1.7
1.8
pH
Fe
Cu
Ni
Co

# Appendix H

## CSTR Pilot Trials - Test Results

## Table H1. Iron Titration Results

| CSTR 15N Total Fe Loadings (gpl) per Tank | | | | | | Feed | CSTR-N Ferric Ion Loadings (gpl) per Tank | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Base load of 0 gpl Fe | | | | | | Date | | | | | | |
| Days | Tank N1A | Tank N1B | Tank N2 | Tank N3 | FT | | Days | Tank N1A | Tank N1B | Tank N2 | Tank N3 | FT |
| 0 | | | | | | 28-Sep-97 | 0 | | | | | |
| 1 | 30.19 | 32.09 | 25.16 | 15.09 | | 29-Sep-97 | 1 | 18.67 | 20.91 | 13.97 | 5.14 | |
| 2 | 30.52 | 22.81 | 25.94 | 21.13 | | 30-Sep-97 | 2 | 16.43 | 10.17 | 13.08 | 9.73 | |
| 3 | 30.86 | 19.12 | 25.71 | 23.81 | | 01-Oct-97 | 3 | 14.76 | 5.37 | 11.74 | 10.40 | |
| 5 | 27.73 | 35.44 | 22.70 | 22.47 | | 03-Oct-97 | 5 | 15.20 | 21.24 | 8.94 | 8.61 | |
| 8 | 22.92 | 15.65 | 20.57 | 15.43 | | 06-Oct-97 | 8 | 7.94 | 4.81 | 9.17 | 4.02 | |
| 9 | 23.81 | 23.48 | 28.73 | 17.66 | | 07-Oct-97 | 9 | 7.04 | 10.40 | 14.53 | 4.25 | |
| 10 | 37.01 | 26.50 | 33.43 | 21.91 | | 08-Oct-97 | 10 | 19.90 | 12.86 | 17.89 | 7.60 | |
| 11 | 31.53 | 28.73 | 35.78 | 30.75 | | 09-Oct-97 | 11 | 13.53 | 13.97 | 19.57 | 15.54 | |
| 12 | 38.01 | 33.88 | 33.65 | 28.40 | | 10-Oct-97 | 12 | 22.02 | 17.11 | 20.01 | 13.86 | |
| 15 | 32.09 | 26.27 | 25.71 | 25.83 | | 13-Oct-97 | 15 | 20.12 | 19.57 | 12.75 | 11.96 | |
| 16 | 21.91 | 14.65 | 29.62 | 31.30 | | 14-Oct-97 | 16 | 10.73 | 7.83 | 14.87 | 17.78 | |
| 17 | 25.94 | 20.79 | 30.63 | 33.88 | | 15-Oct-97 | 17 | 13.08 | 13.08 | 16.32 | 22.70 | |
| 18 | 32.98 | 37.23 | 42.60 | 36.45 | | 16-Oct-97 | 18 | 18.56 | 28.84 | 27.84 | 27.39 | |
| 19 | 28.06 | 29.40 | 25.04 | 34.77 | | 17-Oct-97 | 19 | 18.56 | 22.02 | 13.19 | 25.60 | |
| 22 | 40.81 | 26.50 | 36.78 | 28.06 | | 20-Oct-97 | 22 | 29.95 | 18.89 | 24.26 | 15.43 | |
| Re-cycle load of 10 gpl Fe | | | | | | | | | | | | |
| 23 | 31.75 | 26.16 | 23.14 | 41.37 | 10.96 | 21-Oct-97 | 23 | 17.78 | 16.21 | 7.71 | 26.16 | 7.83 |
| 24 | 33.54 | 27.84 | 31.86 | 33.88 | | 22-Oct-97 | 24 | 20.12 | 18.22 | 18.22 | 19.57 | |
| 25 | 35.89 | 28.51 | 40.81 | 30.30 | | 23-Oct-97 | 25 | 23.37 | 18.78 | 28.51 | 19.01 | |
| 26 | 38.01 | 29.63 | 38.24 | 33.88 | | 24-Oct-97 | 26 | 24.26 | 17.44 | 24.82 | 23.25 | |
| 29 | 30.75 | 32.53 | 22.02 | 23.03 | | 27-Oct-97 | 29 | 16.32 | 22.14 | 9.61 | 12.52 | |
| 30 | 36.11 | 35.33 | 28.40 | 27.84 | 15.99 | 28-Oct-97 | 30 | 24.26 | 25.83 | 18.22 | 18.45 | 13.75 |
| 31 | 37.23 | 32.65 | 30.30 | 26.67 | | 29-Oct-97 | 31 | 20.01 | 19.68 | 15.99 | 15.88 | |
| 32 | 38.35 | 31.75 | 30.97 | 25.38 | | 30-Oct-97 | 32 | 19.34 | 16.32 | 15.32 | 14.42 | |
| 33 | 41.14 | 33.88 | 33.20 | 29.96 | | 31-Oct-97 | 33 | 24.04 | 17.22 | 16.43 | 17.55 | |
| 34 | 44.27 | 41.59 | 39.58 | 33.43 | | 01-Nov-97 | 34 | 23.70 | 23.03 | 21.35 | 19.45 | |
| 36 | 50.87 | 47.18 | 44.94 | 43.83 | 17.89 | 03-Nov-97 | 36 | 24.37 | 24.15 | 23.93 | 28.62 | 14.98 |
| 37 | 47.74 | 46.17 | 44.05 | 35.78 | | 04-Nov-97 | 37 | 16.88 | 18.78 | 17.55 | 18.34 | |
| 39 | 47.29 | 32.76 | 38.68 | 35.66 | | 06-Nov-97 | 39 | 20.57 | 9.61 | 13.75 | 17.78 | |
| 40 | 48.30 | 41.03 | 44.27 | 48.97 | | 07-Nov-97 | 40 | 22.58 | 20.12 | 20.12 | 28.84 | |
| 43 | 51.20 | 50.76 | 51.20 | 56.24 | | 10-Nov-97 | 43 | 27.50 | 31.19 | 28.62 | 34.66 | |
| 44 | 53.11 | 47.29 | 51.54 | 47.96 | | 11-Nov-97 | 44 | 27.84 | 24.48 | 27.73 | 21.91 | |
| 45 | 57.35 | 36.68 | 52.21 | 43.94 | 6.93 | 12-Nov-97 | 45 | 29.63 | 16.10 | 26.16 | 19.79 | 5.37 |
| 46 | 41.37 | 40.70 | 55.34 | 34.10 | | 13-Nov-97 | 46 | 16.43 | 20.57 | 32.53 | 14.87 | |
| 47 | 48.86 | 45.95 | 63.17 | 54.89 | | 14-Nov-97 | 47 | 19.79 | 20.91 | 34.77 | 31.86 | |
| 50 | 48.07 | 40.36 | 45.28 | 34.88 | | 17-Nov-97 | 50 | 23.14 | 20.01 | 22.58 | 13.30 | |
| 51 | 45.84 | 35.78 | 39.24 | 44.16 | 7.83 | 18-Nov-97 | 51 | 17.66 | 14.31 | 14.42 | 18.22 | 6.04 |
| 52 | 44.50 | 33.88 | 42.60 | 46.51 | | 19-Nov-97 | 52 | 15.43 | 10.29 | 13.97 | 19.45 | |
| 53 | 49.30 | 33.65 | 54.78 | 46.73 | | 20-Nov-97 | 53 | 23.81 | 14.65 | 32.09 | 24.82 | |
| 54 | 51.76 | 34.43 | 51.99 | 47.18 | | 21-Nov-97 | 54 | 27.50 | 13.75 | 28.29 | 26.94 | |
| 57 | 42.93 | 34.77 | 39.35 | 34.43 | | 24-Nov-97 | 57 | 19.01 | 17.33 | 18.22 | 15.88 | |
| 58 | 48.19 | 43.15 | 47.85 | 43.83 | 12.97 | 25-Nov-97 | 58 | 16.99 | 22.81 | 23.03 | 20.01 | 11.07 |
| 59 | 47.96 | 36.22 | 43.04 | 41.03 | | 26-Nov-97 | 59 | 18.78 | 17.78 | 18.56 | 19.57 | |
| 60 | 47.63 | 32.65 | 35.44 | 37.79 | | 27-Nov-97 | 60 | 18.78 | 14.98 | 13.19 | 17.89 | |
| Retention time changed from 10d to 15d | | | | | | | | | | | | |
| 1 | 48.52 | 37.01 | 39.80 | 38.46 | | 28-Nov-97 | 1 | 19.23 | 18.56 | 16.21 | 17.55 | |
| 2 | 54.45 | 37.45 | 42.60 | 35.11 | | 01-Dec-97 | 2 | 24.37 | 20.12 | 19.23 | 15.20 | |
| 4 | 55.45 | 33.65 | 42.37 | 34.66 | 15.65 | 03-Dec-97 | 4 | 24.71 | 15.88 | 20.57 | 15.54 | 14.20 |
| 5 | 56.91 | 30.30 | 41.70 | 34.10 | | 04-Dec-97 | 5 | 24.60 | 11.74 | 19.68 | 15.43 | |
| 6 | 54.67 | 32.98 | 42.26 | 34.88 | | 05-Dec-97 | 6 | 23.37 | 13.86 | 19.34 | 15.43 | |
| 9 | 43.04 | 35.22 | 42.93 | 41.93 | | 08-Dec-97 | 9 | 19.90 | 18.11 | 23.81 | 28.51 | |
| 10 | 48.41 | 28.17 | 41.93 | 33.88 | 5.59 | 09-Dec-97 | 10 | 19.01 | 9.95 | 19.34 | 19.79 | 3.91 |
| 11 | 44.61 | 32.87 | 45.28 | 39.91 | | 10-Dec-97 | 11 | 17.33 | 18.11 | 26.94 | 27.50 | |
| 12 | 42.37 | 33.99 | 33.09 | 34.99 | | 11-Dec-97 | 12 | 17.78 | 18.45 | 13.75 | 21.58 | |
| 13 | 39.47 | 35.11 | 39.80 | 36.00 | | 12-Dec-97 | 13 | 15.65 | 19.23 | 19.68 | 19.57 | |
| 16 | 34.66 | 35.11 | 52.55 | 29.18 | | 15-Dec-97 | 16 | 10.96 | 20.35 | 28.84 | 14.98 | |
| 17 | 52.43 | 31.53 | 58.02 | 50.31 | 10.40 | 16-Dec-97 | 17 | 24.71 | 15.32 | 33.76 | 32.98 | 8.72 |
| 18 | 40.70 | 35.33 | 55.12 | 43.71 | | 17-Dec-97 | 18 | 17.78 | 15.99 | 30.07 | 28.06 | |
| 19 | 47.29 | 44.38 | 38.68 | 27.95 | | 18-Dec-97 | 19 | 27.73 | 32.87 | 20.57 | 13.64 | |
| 20 | 44.50 | 41.81 | 47.29 | 36.78 | | 19-Dec-97 | 20 | 24.04 | 24.60 | 25.38 | 20.57 | |

Table H2. Solids Assay on N-CSTR (Day 01: 29-Sep-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 74.64% | 80.47% | 69.60% | 50.54% | 67.23% | 75.98% | 58.00% | 25.66% | 64.99% | 97.49% | 51.77% | 9.14% | 75.34% | 98.27% | 65.96% | 28.51% |
| Weight of Metal | 0.97 | 67.09 | 1.60 | 36.24 | 1.26 | 82.52 | 2.32 | 54.46 | 1.24 | 7.95 | 2.34 | 61.33 | 0.87 | 5.48 | 1.65 | 48.25 |
| Residue Assay | 0.96% | 661 | 1.58% | 35.70% | 0.83% | 544 | 1.53% | 35.90% | 0.92% | 59 | 1.74% | 45.53% | 0.86% | 54 | 1.63% | 47.54% |
| % Solids in Residue | 10.15% | 10.15% | 10.15% | 10.15% | 15.17% | 15.17% | 15.17% | 15.17% | 13.47% | 13.47% | 13.47% | 13.47% | 10.15% | 10.15% | 10.15% | 10.15% |
| Weight of Metal | 3.84 | 343.51 | 5.27 | 73.26 | 3.84 | 343.51 | 5.27 | 73.26 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 16.28% | 16.28% | 16.28% | 16.28% | 16.28% | 16.28% | 16.28% | 16.28% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H3. Solids Assay on N-CSTR (Day 08: 06-Oct-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 70.50% | 77.82% | 69.63% | 45.11% | 70.32% | 78.99% | 60.21% | 37.08% | 76.28% | 83.00% | 71.73% | 37.62% | 79.35% | 86.10% | 76.88% | 40.62% |
| Weight of Metal | 1.35 | 90.87 | 1.91 | 47.97 | 1.36 | 86.10 | 2.50 | 54.99 | 0.84 | 53.81 | 1.37 | 42.10 | 0.73 | 44.01 | 1.12 | 40.08 |
| Residue Assay | 1.04% | 699 | 1.47% | 36.90% | 0.94% | 595 | 1.73% | 38.00% | 0.66% | 423 | 1.08% | 33.10% | 0.54% | 325 | 0.83% | 29.60% |
| % Solids in Residue | 13.00% | 13.00% | 13.00% | 13.00% | 14.47% | 14.47% | 14.47% | 14.47% | 12.72% | 12.72% | 12.72% | 12.72% | 13.54% | 13.54% | 13.54% | 13.54% |
| Weight of Metal | 4.58 | 409.76 | 6.29 | 87.39 | 4.58 | 409.76 | 6.29 | 87.39 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 19.42% | 19.42% | 19.42% | 19.42% | 19.42% | 19.42% | 19.42% | 19.42% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H4. Solids Assay on N-CSTR (Day 15: 13-Oct-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 52.97% | 64.63% | 23.33% | 10.03% | 59.07% | 69.06% | 34.80% | 15.08% | | | | | | | | |
| Weight of Metal | 1.77 | 118.89 | 3.96 | 64.50 | 1.54 | 104.00 | 3.37 | 60.88 | | | | | | | | |
| Residue Assay | 1.05% | 706 | 2.35% | 38.30% | 0.91% | 615 | 1.99% | 36.00% | | | | | | | | |
| % Solids in Residue | 16.84% | 16.84% | 16.84% | 16.84% | 16.91% | 16.91% | 16.91% | 16.91% | | | | | | | | |
| Weight of Metal | 3.76 | 336.12 | 5.16 | 71.69 | 3.76 | 336.12 | 5.16 | 71.69 | | | | | | | | |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | | | | | | | | |
| % Solids | 15.93% | 15.93% | 15.93% | 15.93% | 15.93% | 15.93% | 15.93% | 15.93% | | | | | | | | |

Table H5. Solids Assay on N-CSTR (Day 18: 16-Oct-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 60.00% | 72.41% | 48.23% | 44.00% | 57.92% | 71.17% | 38.77% | 32.41% | 69.45% | 78.05% | 61.12% | 40.15% | 76.09% | 83.03% | 67.49% | 51.68% |
| Weight of Metal | 1.46 | 90.04 | 2.60 | 38.99 | 1.54 | 94.11 | 3.17 | 47.06 | 1.12 | 71.64 | 1.95 | 41.66 | 0.87 | 55.41 | 1.63 | 33.64 |
| Residue Assay | 1.21% | 746 | 2.15% | 32.30% | 1.11% | 680 | 2.29% | 34.00% | 0.83% | 533 | 1.45% | 31.00% | 0.75% | 476 | 1.40% | 28.90% |
| % Solids in Residue | 12.07% | 12.07% | 12.07% | 12.07% | 13.84% | 13.84% | 13.84% | 13.84% | 13.44% | 13.44% | 13.44% | 13.44% | 11.64% | 11.64% | 11.64% | 11.64% |
| Weight of Metal | 3.65 | 326.42 | 5.01 | 69.62 | 3.65 | 326.42 | 5.01 | 69.62 | 3.65 | 326.42 | 5.01 | 69.62 | 3.65 | 326.42 | 5.01 | 69.62 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% | 15.47% |

Table H6. Solids Assay on N-CSTR (Day 22: 20-Oct-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 52.20% | 66.84% | 37.86% | 30.23% | 44.08% | 62.52% | 23.14% | 19.35% | 57.50% | 70.68% | 48.56% | 26.80% | 65.52% | 75.59% | 53.90% | 30.86% |
| Weight of Metal | 1.72 | 108.70 | 3.07 | 47.88 | 2.01 | 120.59 | 3.80 | 55.34 | 1.53 | 94.35 | 2.64 | 50.23 | 1.24 | 78.55 | 2.28 | 47.44 |
| Residue Assay | 1.13% | 702 | 2.02% | 31.50% | 1.24% | 743 | 2.34% | 34.10% | 0.95% | 588 | 1.64% | 31.20% | 0.79% | 500 | 1.45% | 30.20% |
| % Solids in Residue | 15.20% | 15.20% | 15.20% | 15.20% | 16.23% | 16.23% | 16.23% | 16.23% | 16.10% | 16.10% | 16.10% | 16.10% | 15.71% | 15.71% | 15.71% | 15.71% |
| Weight of Metal | 3.60 | 321.78 | 4.94 | 68.63 | 3.60 | 321.78 | 4.94 | 68.63 | 3.60 | 321.78 | 4.94 | 68.63 | 3.60 | 321.78 | 4.94 | 68.63 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% | 15.25% |

Table H7. Solids Assay on N-CSTR (Day 26: 23-Oct-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 48.51% | 63.81% | 36.86% | 24.84% | 46.87% | 62.93% | 29.48% | 20.42% | 61.48% | 72.12% | 51.66% | 24.08% | 66.76% | 75.92% | 54.90% | 36.80% |
| Weight of Metal | 1.82 | 114.53 | 3.07 | 50.73 | 1.88 | 117.32 | 3.43 | 53.72 | 1.38 | 88.23 | 2.35 | 51.26 | 1.18 | 76.20 | 2.19 | 42.66 |
| Residue Assay | 1.20% | 754 | 2.02% | 33.40% | 1.18% | 736 | 2.15% | 33.70% | 0.83% | 537 | 1.43% | 31.20% | 0.80% | 518 | 1.49% | 29.00% |
| % Solids in Residue | 15.19% | 15.19% | 15.19% | 15.19% | 15.94% | 15.94% | 15.94% | 15.94% | 16.43% | 16.43% | 16.43% | 16.43% | 14.71% | 14.71% | 14.71% | 14.71% |
| Weight of Metal | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H8. Solids Assay on N-CSTR (Day 29: 27-Oct-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 54.09% | 67.22% | 41.87% | 26.86% | 50.47% | 68.46% | 36.04% | 22.54% | 59.16% | 71.50% | 50.98% | 23.08% | 67.58% | 76.70% | 57.32% | 36.15% |
| Weight of Metal | 1.63 | 103.75 | 2.83 | 49.37 | 1.75 | 106.16 | 3.11 | 52.28 | 1.45 | 90.20 | 2.38 | 51.92 | 1.15 | 73.55 | 2.07 | 43.10 |
| Residue Assay | 1.07% | 683 | 1.86% | 32.50% | 1.10% | 666 | 1.95% | 32.80% | 0.88% | 549 | 1.45% | 31.60% | 0.78% | 500 | 1.41% | 29.30% |
| % Solids in Residue | 15.19% | 15.19% | 15.19% | 15.19% | 15.94% | 15.94% | 15.94% | 15.94% | 16.43% | 16.43% | 16.43% | 16.43% | 14.71% | 14.71% | 14.71% | 14.71% |
| Weight of Metal | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H9. Solids Assay on N-CSTR (Day 32: 30-Oct-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 58.47% | 65.67% | 45.84% | 36.12% | 57.09% | 68.95% | 41.95% | 26.29% | 66.69% | 74.49% | 60.22% | 37.85% | 73.60% | 79.10% | 62.22% | 40.40% |
| Weight of Metal | 1.47 | 108.64 | 2.63 | 43.12 | 1.52 | 98.27 | 2.82 | 49.76 | 1.18 | 80.75 | 1.93 | 41.95 | 0.93 | 66.15 | 1.84 | 40.23 |
| Residue Assay | 1.05% | 776 | 1.88% | 30.80% | 0.98% | 634 | 1.82% | 32.10% | 0.86% | 589 | 1.41% | 30.60% | 0.69% | 490 | 1.36% | 29.80% |
| % Solids in Residue | 14.00% | 14.00% | 14.00% | 14.00% | 15.50% | 15.50% | 15.50% | 15.50% | 13.71% | 13.71% | 13.71% | 13.71% | 13.50% | 13.50% | 13.50% | 13.50% |
| Weight of Metal | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H10. Solids Assay on N-CSTR (Day 36: 03-Nov-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 51.53% | 61.75% | 47.46% | 39.96% | 51.59% | 66.57% | 48.58% | 35.90% | 69.49% | 75.85% | 66.91% | 49.16% | 75.01% | 79.70% | 69.58% | 49.90% |
| Weight of Metal | 1.72 | 121.05 | 2.55 | 40.53 | 1.71 | 105.81 | 2.50 | 43.27 | 1.08 | 76.44 | 1.61 | 34.32 | 0.88 | 64.24 | 1.48 | 33.81 |
| Residue Assay | 1.27% | 896 | 1.89% | 30.00% | 1.20% | 741 | 1.75% | 30.30% | 0.90% | 637 | 1.34% | 28.60% | 0.73% | 530 | 1.22% | 27.90% |
| % Solids in Residue | 13.51% | 13.51% | 13.51% | 13.51% | 14.28% | 14.28% | 14.28% | 14.28% | 12.00% | 12.00% | 12.00% | 12.00% | 12.12% | 12.12% | 12.12% | 12.12% |
| Weight of Metal | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H11. Solids Assay on N-CSTR (Day 39: 06-Nov-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 41.58% | 65.57% | 47.39% | 29.15% | 40.91% | 68.52% | 48.93% | 23.21% | 56.71% | 76.14% | 62.88% | 39.75% | 69.44% | 83.06% | 72.00% | 46.95% |
| Weight of Metal | 1.69 | 85.21 | 2.80 | 42.09 | 1.71 | 77.92 | 2.72 | 45.61 | 1.25 | 59.04 | 1.98 | 35.79 | 0.88 | 41.94 | 1.49 | 31.51 |
| Residue Assay | 1.31% | 680 | 2.17% | 32.60% | 1.17% | 533 | 1.86% | 31.20% | 0.97% | 457 | 1.53% | 27.70% | 0.73% | 346 | 1.23% | 26.00% |
| % Solids in Residue | 12.91% | 12.91% | 12.91% | 12.91% | 14.62% | 14.62% | 14.62% | 14.62% | 12.92% | 12.92% | 12.92% | 12.92% | 12.12% | 12.12% | 12.12% | 12.12% |
| Weight of Metal | 2.90 | 247.50 | 5.33 | 59.40 | 2.90 | 247.50 | 5.33 | 59.40 | 2.90 | 247.50 | 5.33 | 59.40 | 2.90 | 247.50 | 5.33 | 59.40 |
| Head Grade | 1.93% | 1650 | 3.55% | 39.60% | 1.93% | 1650 | 3.55% | 39.60% | 1.93% | 1650 | 3.55% | 39.60% | 1.93% | 1650 | 3.55% | 39.60% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H12. Solids Assay on N-CSTR (Day 45: 10-Nov-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 50.39% | 73.90% | 37.05% | 30.28% | 51.40% | 75.14% | 35.43% | 24.72% | 69.45% | 83.99% | 63.81% | 49.23% | 74.41% | 86.71% | 68.85% | 59.00% |
| Weight of Metal | 1.76 | 82.59 | 3.06 | 47.06 | 1.72 | 78.69 | 3.14 | 50.82 | 1.08 | 50.69 | 1.76 | 34.27 | 0.91 | 42.07 | 1.51 | 27.67 |
| Residue Assay | 1.28% | 602 | 2.23% | 34.30% | 1.08% | 494 | 1.97% | 31.90% | 0.83% | 389 | 1.35% | 26.30% | 0.73% | 339 | 1.22% | 22.30% |
| % Solids in Residue | 13.72% | 13.72% | 13.72% | 13.72% | 15.93% | 15.93% | 15.93% | 15.93% | 13.03% | 13.03% | 13.03% | 13.03% | 12.41% | 12.41% | 12.41% | 12.41% |
| Weight of Metal | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H13 . Solids Assay on N-CSTR (Day 48: 13-Nov-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 47.18% | 59.61% | 39.09% | 34.49% | 53.11% | 66.42% | 53.37% | 26.99% | 67.64% | 77.21% | 71.59% | 46.26% | 76.46% | 83.21% | 76.25% | 52.71% |
| Weight of Metal | 1.81 | 117.53 | 3.01 | 41.57 | 1.61 | 97.72 | 2.30 | 46.33 | 1.11 | 66.31 | 1.40 | 34.10 | 0.81 | 48.87 | 1.17 | 30.00 |
| Residue Assay | 1.34% | 868 | 2.22% | 30.70% | 1.05% | 637 | 1.50% | 30.20% | 0.88% | 525 | 1.11% | 27.00% | 0.69% | 417 | 1.00% | 25.60% |
| % Solids in Residue | 13.54% | 13.54% | 13.54% | 13.54% | 15.34% | 15.34% | 15.34% | 15.34% | 12.63% | 12.63% | 12.63% | 12.63% | 11.72% | 11.72% | 11.72% | 11.72% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H14. Solids Assay on N-CSTR (Day 52: 17-Nov-97)

|  | N1A |  |  |  | N1B |  |  |  | N2 |  |  |  | N3 |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 47.28% | 64.38% | 32.93% | 39.96% | 56.09% | 69.93% | 50.34% | 27.70% | 63.68% | 74.14% | 59.61% | 47.43% | 77.14% | 82.92% | 73.89% | 54.75% |
| Weight of Metal | 1.81 | 103.67 | 3.31 | 38.09 | 1.51 | 87.50 | 2.45 | 45.87 | 1.25 | 75.26 | 1.99 | 33.36 | 0.79 | 49.69 | 1.29 | 28.71 |
| Residue Assay | 1.45% | 830 | 2.65% | 30.50% | 0.96% | 557 | 1.56% | 29.20% | 0.92% | 555 | 1.47% | 24.60% | 0.64% | 405 | 1.05% | 23.40% |
| % Solids in Residue | 12.49% | 12.49% | 12.49% | 12.49% | 15.71% | 15.71% | 15.71% | 15.71% | 13.56% | 13.56% | 13.56% | 13.56% | 12.27% | 12.27% | 12.27% | 12.27% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H15. Solids Assay on N-CSTR (Day 55: 20-Nov-97)

|  | N1A |  |  |  | N1B |  |  |  | N2 |  |  |  | N3 |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 30.11% | 43.45% | 19.04% | 34.30% | 55.14% | 64.64% | 43.76% | 28.97% | 62.67% | 74.69% | 64.22% | 44.36% | 68.00% | 82.88% | 74.72% | 51.47% |
| Weight of Metal | 2.47 | 178.98 | 3.93 | 44.35 | 1.59 | 111.93 | 2.73 | 47.95 | 1.32 | 80.12 | 1.74 | 37.56 | 1.13 | 54.19 | 1.23 | 32.76 |
| Residue Assay | 1.88% | 1360 | 2.99% | 33.70% | 1.04% | 733 | 1.79% | 31.40% | 0.95% | 576 | 1.25% | 27.00% | 0.83% | 397 | 0.90% | 24.00% |
| % Solids in Residue | 13.16% | 13.16% | 13.16% | 13.16% | 15.27% | 15.27% | 15.27% | 15.27% | 13.91% | 13.91% | 13.91% | 13.91% | 13.65% | 13.65% | 13.65% | 13.65% |
| Weight of Metal | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H16. Solids Assay on N-CSTR (Day 59: 24-Nov-97)

|  | N1A |  |  |  | N1B |  |  |  | N2 |  |  |  | N3 |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 46.44% | 34.41% | 14.32% | 38.49% | 45.15% | 61.23% | 44.20% | 20.14% | 61.01% | 72.41% | 59.94% | 34.13% | 76.58% | 76.30% | 71.03% | 49.11% |
| Weight of Metal | 1.90 | 207.60 | 4.16 | 41.52 | 1.94 | 122.70 | 2.71 | 53.90 | 1.38 | 87.33 | 1.95 | 44.46 | 0.83 | 75.01 | 1.41 | 34.35 |
| Residue Assay | 1.58% | 1730 | 3.47% | 34.60% | 1.16% | 733 | 1.62% | 32.20% | 0.95% | 601 | 1.34% | 30.60% | 0.63% | 570 | 1.07% | 26.10% |
| % Solids in Residue | 12.00% | 12.00% | 12.00% | 12.00% | 16.74% | 16.74% | 16.74% | 16.74% | 14.53% | 14.53% | 14.53% | 14.53% | 13.16% | 13.16% | 13.16% | 13.16% |
| Weight of Metal | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 | 3.54 | 316.50 | 4.86 | 67.50 |
| Head Grade | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% | 2.36% | 2110 | 3.24% | 45.00% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table H17. Solids Assay on N-CSTR (Day 62: 27-Nov-97)

|  | N1A |  |  |  | N1B |  |  |  | N2 |  |  |  | N3 |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 15.28% | 11.34% | -13.68% | 19.39% | 58.95% | 64.07% | 55.02% | 27.90% | 59.83% | 64.43% | 59.27% | 34.28% | 68.56% | 70.98% | 72.34% | 45.15% |
| Weight of Metal | 2.91 | 258.00 | 5.61 | 51.15 | 1.41 | 104.55 | 2.22 | 45.75 | 1.38 | 103.50 | 2.01 | 41.70 | 1.08 | 84.45 | 1.37 | 34.80 |
| Residue Assay | 1.94% | 1720 | 3.74% | 34.10% | 0.94% | 697 | 1.48% | 30.50% | 0.92% | 690 | 1.34% | 27.80% | 0.72% | 563 | 0.91% | 23.20% |
| % Solids in Residue | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table 18. Solids Assay on N-CSTR (Day 66: 01-Dec-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 24.45% | 32.99% | -1.22% | 29.79% | 58.52% | 68.56% | 58.36% | 33.33% | 64.63% | 71.60% | 70.21% | 41.13% | 67.89% | 72.53% | 75.99% | 52.96% |
| Weight of Metal | 2.60 | 195.00 | 5.00 | 44.55 | 1.43 | 91.50 | 2.06 | 42.30 | 1.22 | 82.65 | 1.47 | 37.35 | 1.11 | 79.95 | 1.19 | 29.85 |
| Residue Assay | 1.73% | 1300 | 3.33% | 29.70% | 0.95% | 610 | 1.37% | 28.20% | 0.81% | 551 | 0.98% | 24.90% | 0.74% | 533 | 0.79% | 19.90% |
| % Solids in Residue | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table 19. Solids Assay on N-CSTR (Day 69: 04-Dec-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 38.13% | 45.66% | 18.23% | 43.18% | 59.84% | 70.76% | 64.51% | 33.07% | 70.84% | 78.37% | 76.07% | 42.98% | 76.25% | 82.40% | 80.10% | 43.56% |
| Weight of Metal | 2.13 | 158.13 | 4.04 | 36.05 | 1.38 | 85.10 | 1.75 | 42.47 | 1.00 | 62.94 | 1.18 | 36.18 | 0.82 | 51.22 | 0.98 | 35.81 |
| Residue Assay | 1.68% | 1250 | 3.19% | 28.50% | 0.89% | 549 | 1.13% | 27.40% | 0.67% | 421 | 0.79% | 24.20% | 0.54% | 339 | 0.65% | 23.70% |
| % Solids in Residue | 12.65% | 12.65% | 12.65% | 12.65% | 15.50% | 15.50% | 15.50% | 15.50% | 14.95% | 14.95% | 14.95% | 14.95% | 15.11% | 15.11% | 15.11% | 15.11% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table 20. Solids Assay on N-CSTR (Day 73: 08-Dec-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 48.63% | 50.81% | 40.74% | 43.60% | 64.27% | 72.64% | 70.16% | 29.65% | 75.93% | 80.16% | 77.66% | 45.27% | 80.44% | 84.20% | 80.94% | 44.29% |
| Weight of Metal | 1.76 | 143.14 | 2.92 | 35.79 | 1.23 | 79.61 | 1.47 | 44.64 | 0.83 | 57.74 | 1.10 | 34.73 | 0.67 | 45.96 | 0.94 | 35.35 |
| Residue Assay | 1.43% | 1160 | 2.37% | 29.00% | 0.80% | 519 | 0.96% | 29.10% | 0.60% | 419 | 0.80% | 25.20% | 0.50% | 342 | 0.70% | 26.30% |
| % Solids in Residue | 12.34% | 12.34% | 12.34% | 12.34% | 15.34% | 15.34% | 15.34% | 15.34% | 13.78% | 13.78% | 13.78% | 13.78% | 13.44% | 13.44% | 13.44% | 13.44% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table 21. Solids Assay on N-CSTR (Day 76: 11-Dec-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 44.51% | 47.85% | 30.14% | 43.56% | 61.60% | 70.24% | 63.29% | 26.87% | 73.81% | 79.12% | 73.64% | 45.69% | 84.27% | 87.09% | 82.21% | 46.34% |
| Weight of Metal | 1.91 | 151.75 | 3.45 | 35.81 | 1.32 | 86.60 | 1.81 | 46.40 | 0.90 | 60.76 | 1.30 | 34.46 | 0.54 | 37.56 | 0.88 | 34.05 |
| Residue Assay | 1.57% | 1250 | 2.84% | 29.50% | 0.83% | 545 | 1.14% | 29.20% | 0.65% | 439 | 0.94% | 24.90% | 0.40% | 278 | 0.65% | 25.20% |
| % Solids in Residue | 12.14% | 12.14% | 12.14% | 12.14% | 15.89% | 15.89% | 15.89% | 15.89% | 13.84% | 13.84% | 13.84% | 13.84% | 13.51% | 13.51% | 13.51% | 13.51% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table 22. Solids Assay on N-CSTR (Day 80; 15-Dec-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 45.17% | 48.31% | 30.61% | 42.75% | 67.84% | 74.33% | 71.94% | 27.66% | 65.53% | 71.45% | 64.01% | 28.96% | 84.00% | 87.04% | 80.51% | 41.52% |
| Weight of Metal | 1.88 | 150.43 | 3.42 | 36.32 | 1.10 | 74.69 | 1.38 | 45.90 | 1.18 | 83.09 | 1.78 | 45.08 | 0.55 | 37.72 | 0.96 | 37.11 |
| Residue Assay | 1.54% | 1230 | 2.80% | 29.70% | 0.71% | 480 | 0.89% | 29.50% | 0.62% | 435 | 0.93% | 23.60% | 0.36% | 247 | 0.63% | 24.30% |
| % Solids in Residue | 12.23% | 12.23% | 12.23% | 12.23% | 15.56% | 15.56% | 15.56% | 15.56% | 19.10% | 19.10% | 19.10% | 19.10% | 15.27% | 15.27% | 15.27% | 15.27% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Table 23. Solids Assay on N-CSTR (Day 83; 18-Dec-97)

| | N1A | | | | N1B | | | | N2 | | | | N3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron | Nickel | Cobalt | Copper | Iron |
| % Metal Extraction | 52.10% | 53.99% | 49.06% | 52.16% | 68.36% | 76.31% | 66.21% | 36.87% | 75.23% | 80.58% | 78.27% | 37.77% | 84.76% | 87.92% | 81.51% | 44.36% |
| Weight of Metal | 1.65 | 133.88 | 2.51 | 30.35 | 1.09 | 68.94 | 1.67 | 40.05 | 0.85 | 56.51 | 1.07 | 39.49 | 0.52 | 35.16 | 0.91 | 35.31 |
| Residue Assay | 1.61% | 1310 | 2.46% | 29.70% | 0.73% | 463 | 1.12% | 26.90% | 0.50% | 332 | 0.63% | 23.20% | 0.35% | 235 | 0.61% | 23.60% |
| % Solids in Residue | 10.22% | 10.22% | 10.22% | 10.22% | 14.89% | 14.89% | 14.89% | 14.89% | 17.02% | 17.02% | 17.02% | 17.02% | 14.96% | 14.96% | 14.96% | 14.96% |
| Weight of Metal | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 | 3.44 | 291.00 | 4.94 | 63.45 |
| Head Grade | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% | 2.29% | 1940 | 3.29% | 42.30% |
| % Solids | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% | 15.00% |

Figure H1. CSTR-N(15%)

TUNS Concentrate

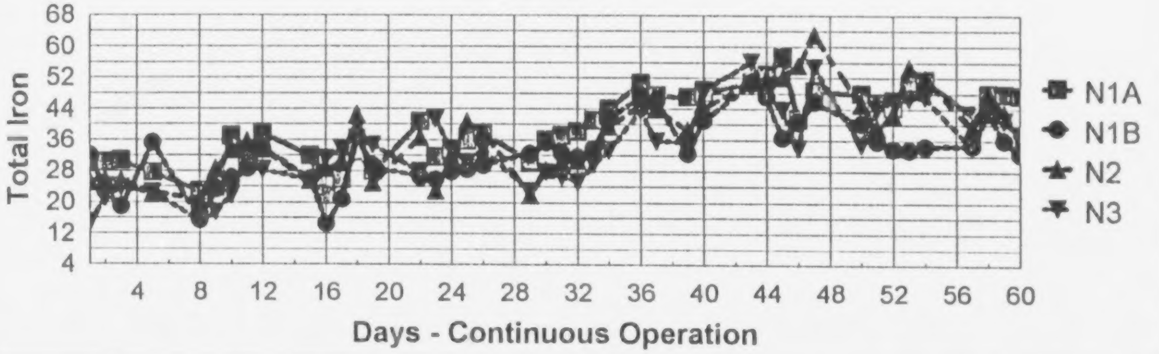


Figure H2. CSTR-N(15%)

TUNS Concentrate

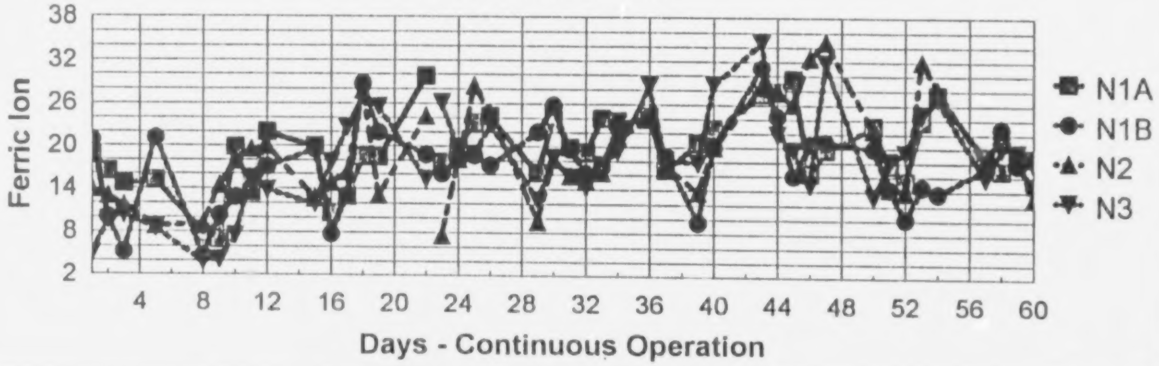


**Figure H3. CSTR-N(15%)**

TUNS Concentrate
Retention Time = 15 days

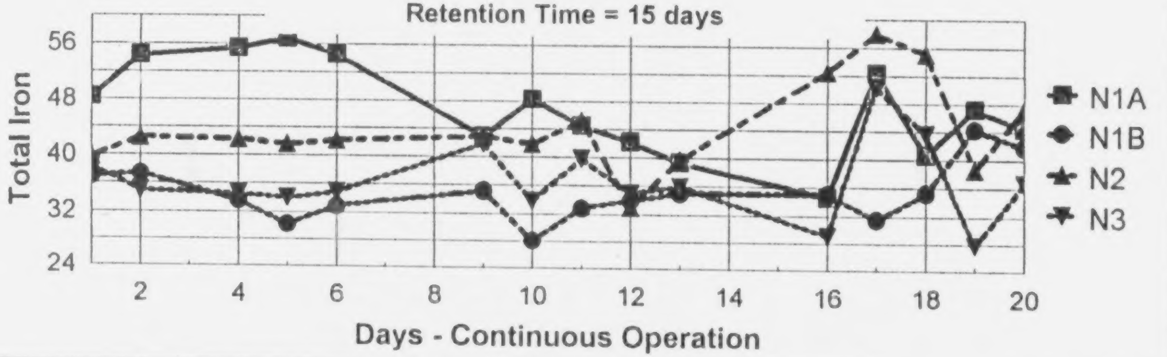


**Figure H4. CSTR-N(15%)**

TUNS Concentrate
Retention Time = 15 days